B 02

The Canadian Entomologist

VOLUME XCIII FEBRUARY 1961 NUMBER 2

OHIO STATE UNIVERSITY
MAR 13 1961
LIBRARY

CONTENTS

CHILLCOTT—Ten New Species of *Fannia* R.-D. (Diptera: Muscidae) from the Palaearctic and Oriental Regions 81

PIELOU and WILLIAMS—The Effectiveness of Residues of Insecticides in Preventing Reinfestation of Apple Leaves by Apple Aphid, *Aphis pomi* DeG. I. Diazinon, Trithion and Sevin 93

PERRON and LAFRANCE—Notes on the Life-History of the Onion Maggot, *Hylemyia antiqua* (Meig.) (Diptera: Anthomyiidae) Reared in Field Cages 101

BROWN—*Coenonympha tullia* on Islands in the St. Lawrence River 107

PILON and BLAIS—Weather and Outbreaks of the Spruce Budworm in the Province of Quebec from 1939 to 1956 118

CONDRASHOFF—Three New Species of *Contarinia* Rond. (Diptera: Cecidomyiidae) in Douglas-Fir Needles 123

MORRIS—Life-History and Habits in Newfoundland of *Swammerdamia lutarea* (Haw.) (Lepidoptera: Yponomeutidae), a Pest New to North America 130

CUMING—The Distribution, Life History, and Economic Importance of the Winter Moth, *Operophtera brumata* (L.) (Lepidoptera, Geometridae) in Nova Scotia 135

HOBBS, NUMMI, and VIROSTEK—*Anthophora occidentalis* Cress. (Hymenoptera: Apidae) and its Associates at a Nesting Site in Southern Alberta 142

WEINTRAUB—Inducing Mating and Oviposition of the Warble Flies *Hypoderma bovis* (L.) and *H. lineatum* (De Vill.) (Diptera: Oestridae) in Captivity 149

ROBINSON—Some Problems Associated with Weighing Aphids That Have Fed After Starving, as a Method of Measuring Intake of Plant Sap 156

PUBLISHED MONTHLY

by the Entomological Society of Canada and the Entomological Society of Ontario with the assistance of Le Ministère de l'Agriculture de la Province de Québec.

AUTHORIZED AS SECOND CLASS MAIL BY POST OFFICE DEPARTMENT, OTTAWA, pp. 91

The Canadian Entomologist

Editor: Dr. Eugene Munroe, Entomology Research Institute, Research Branch, Canada Agriculture, Central Experimental Farm, Ottawa.

EDITORIAL BOARD

Dr. R. Glen, Research Branch, Canada Department of Agriculture, Ottawa.
Dr. H. Hurtig, Research Branch, Canada Department of Agriculture, Ottawa.
Dr. H. H. J. Nesbitt, Department of Biology, Carleton University, Ottawa.
Dr. J. Stanley, Department of Zoology, McGill University, Montreal.
Dr. F. A. Urquhart, Division of Zoology and Palaeontology, The Royal Ontario Museum, Toronto.

SUBSCRIPTIONS

The subscription price is $10.00 per year, payable in advance. This price includes postage but not currency or bank exchange, which must be calculated to yield the full subscription price in Ottawa. Subscribers receive the *Annual Report of the Entomological Society of Ontario*, through the courtesy of the Ontario Department of Agriculture, and also the supplements to *The Canadian Entomologist*. Back numbers beginning with Volume 90 are available at $1.00 per number and $10.50 per volume, including postage; those prior to volume 90 are priced at 75c per number and $6.50 per volume.

Correspondence regarding payments or change of address should be directed to the Treasurer; information on back numbers and exchanges should be obtained from the Secretary.

MEMBERSHIP IN THE ENTOMOLOGICAL SOCIETY OF CANADA

Regular membership is open to all persons interested in entomology. The annual membership fee, payable in advance, is $8.00 for direct membership or $6.00 through a regional affiliated society. Members receive *The Canadian Entomologist* and its supplements and, through the courtesy of the Ontario Department of Agriculture, the *Annual Report of the Entomological Society of Ontario*. Application for membership should be made to the Secretary or to one of the affiliated societies.

Sustaining membership is open to organizations wishing to support the Society for an annual fee of $100.00. Sustaining members receive *The Canadian Entomologist* and may assign to a representative or proxy all privileges of a regular membership except the holding of office.

Student membership, at $3.00 is open for one year to university students in the graduating year, on recommendation by the president of a regional affiliated society, or by a professor who is a member of the Entomological Society of Canada. Extension of this privilege for an additional year is permissible on renewed application, subject to approval of the Executive Committee of the Board of Directors.

Articles for publication in *The Canadian Entomologist* are ordinarily accepted only from members of the Society.

The Canadian Entomologist

Vol. XCIII Ottawa, Canada, February 1961 No. 2

Ten New Species of *Fannia* R.-D. (Diptera: Muscidae) from the Palaearctic and Oriental Regions

By J. G. CHILLCOTT

Entomology Research Institute, Research Branch,
Canada Department of Agriculture, Ottawa, Ontario

The following descriptions and notes are based on Palaearctic material of Fanniinae in the U.S. National Museum, Washington, D.C., and on Indian material in the Canadian National Collection of Insects, Ottawa. One new species is described from Tunisia, one from India, two from Japan, and six from Szechuen province near the China-Tibet border in China. Special thanks are due Dr. R. H. Foote of the U.S. National Museum for making this material available to me.

The list of previously known species of Fanniinae from the eastern Palaearctic region is very small. Only eleven species have been recorded, and of these, seven are cosmopolitan or at least generally Holarctic. These are: *Fannia canicularis* (L.), *F. scalaris* (Fab.), *F. incisurata* (Meig.), *F. leucosticta* (Meig.), *F. glaucescens* (Zett.), *F. minutipalpis* (Stein), and *Euryomma peregrinum* (Meig.). The other four species appear to be endemic to the region. These are: *F. kikowensis* Ouchi from Chekiang province, China; *F. prisca* Stein from Korea, Formosa, and south China; *F. interrupta* Malloch from Formosa; and *Xestomyia hirtifemur* Stein from Tibet. No endemic species are known from India.

In the material before me, I have representative specimens of all the general Holarctic species except *F. incisurata* and *E. peregrinum*, as well as several specimens of *F. prisca* from China and Korea. I have not seen any material of the three other endemic species.

This paper is preliminary to a revision of the Fanniinae of the world.

The form and terminology of the descriptions as well as the composition of species groups and complexes follow my "Revision of the Nearctic Species of the Subfamily Fanniinae (Muscidae: Diptera)", Canadian Entomologist Supplement 14, 1960.

Fannia prolata, new species

This species belongs to the *incisurata* complex of the *scalaris* group. It can be separated from related species by the hairy eyes, the indistinctly marked abdominal vitta, and elongate body shape. Length 8.5 mm.

Male

Head.—Frontal bristles 11-14, strong, extending almost to ocellar triangle. Parafrontals narrow (0.06 increasing to 0.20 mm.), silvery-pollinose. Occipital bristles short, regular; postoccipital bristles numerous, not in regular rows. Second antennal segment dark reddish-brown, with a single long bristle; third segment black, two and one half times as long as broad; arista subpubescent. Palpus black, subspatulate; theca weakly pollinose, weakly sclerotized.

Thorax.—Pale greyish-brown with four distinct brown vittae between the bristle rows. Acrosticals quadriserial, becoming irregular behind the suture. Accessory setulae numerous. Prealar bristles two, distinctly stronger than accessory setulae. Stigmatals numerous. Mesopleural setulae long, moderate in

number. Scutellum sparsely setulose except medially at base. Squamae pale, margins concolorous, lower squama projecting. Haltere yellow, wing weakly infuscated.

Abdomen.—2.0 by 3.9 mm. Pale grey-pollinose, with a linear median vitta slightly expanded at posterior margins of the segments.

Legs.—Black, not even the knees paler. F_1 posteroventrals numerous, weak basally, becoming distinctly stronger apicad. T_1 with a weak anterodorsal and 2 strong posteroventral bristles medially. F_2 anteroventrals with four strong bristles on basal half equal to femoral diameter, followed by 15 shorter, distinctly closer-set bristles to apex; posteroventrals as a row of strong bristles slightly closer-set toward apex of femur. T_2 ventral mat distinctly longer on apical portion; one anterodorsal, one posterodorsal. Mt_2 unmodified. C_3 with two or three posteroventral bristles. F_3 setulose at base with five to seven distinct bristles on apical half; posteroventrals as irregular, long setulae of equal length throughout. T_3 with row of anteroventrals, of which about eight are strong; only one strong anterodorsal; numerous posteroventrals commencing one-fourth of tibial length from base.

Hypopygium.—Typical of the *scalaris* subgroup.

Female

Not as yet known.

Types

Holotype.—♂, Suifu, Szechuen, China, 4.XII.1927 (D. C. Graham) (U.S.N.M.No. 64539).

Paratype.—♂, same locality and collector, 11.XII.1923 (C.N.C. No. 7084).

***Fannia nudiseta*, new species**

This species is very similar to the preceding, but differs in that it possesses distinct sternopleural and mid-coxal thorns, which place it in the *fuscula* subgroup of the *scalaris* group. It is related to *kikowensis* Ouchi and *vesparia* (Meade), but differs from both in having numerous long anteroventral and posteroventral bristles on the hind tibia. It differs also from *kikowensis* in having the mid-coxal thorns strongly hooked. Length 8.5 mm.

Male

Head.—Frontal bristles about 18, strong, extending almost to ocellar triangle. Parafrontals moderately broad (0.04 increasing to 0.18 mm.), silvery-pollinose. Occipital bristles long, fine, irregular; postoccipital bristles absent near mid-dorsal line, numerous laterally. Second antennal segment dark reddish-brown with a single strong bristle; third segment black, 2½ times as long as broad; arista almost entirely bare with a faint trace of pubescence under high power. Palpus weakly spatulate; theca slightly pollinose, weakly sclerotized.

Thorax.—Dark brownish-grey with no trace of vitae. Acrosticals biserial presuturally, becoming quadriserial in front of the scutellum, anterior two pair of acrosticals distinctly stronger. Accessory setulae moderately strong, sparse. Prealars two or three, distinctly stronger than accessory setulae. Stigmatal and mesopleural setulae numerous. Sternopleural spine long and strong. Scutellum bare on median basal portion. Squamae pale yellow, margins darker, lower squama projecting. Haltere orange, wing pale yellowish-brown.

Abdomen.—2.0 by 4.2 mm. Distinctly grey-pollinose, with brown median vitta distinctly broadened at posterior margins of segments.

Legs.—Dark reddish-brown, knees only slightly paler. F_1 with full row of bristles becoming stronger apicad. T_1 with two or three weak posteroventral bristles. C_2 apically with a strong hooked bristle. F_2 anteroventrals with six weak bristles on basal half, then six strong, closer-set bristles to three-fourths, followed by an apical comb of short bristles; posteroventrals strong, uniserial on basal half, becoming shorter and triserial to four-fifths, then a very short preapical comb. T_2 slender on basal half, abruptly expanded to twice basal diameter on apical half. Mt_2 unmodified. C_3 posteroventrally usually with only one distinct bristle. F_3 anteroventrals short-setulose except for five strong bristles on apical fourth, posteroventrals short setulose. T_3 with numerous ventral and anteroventral bristles, a full row of anterodorsals, and numerous posteroventrals on median three-fifths.

Hypopygium.—Typical of the *vesparia* complex.

Female

Not as yet known.

Type

Holotype.— ♂, nr. Yien, Long Shien, China-Tibet border, 13-15000 ft., 3-6. VIII. 1930 (D. C. Graham) (U.S.N.M. No. 64540).

Fannia grahami, new species

Figs. 1, 7

This species is a member of the *mutica* group but can be separated from the other species by the combination of yellow squamae, two hind-tibial anteroventrals, and dull grey parafrontals in the male. Length about 5.5 mm.

Male

Head.—Frontal bristles about 12, long, fine, with several interstitials extending almost to ocellar triangle. Parafrontals narrow (0.03 increasing to 0.12 mm.), contiguous or scarcely separated, dull grey in color. Occipital bristles long, slender, irregular; postoccipital bristles scarcely extended dorsad. Antenna black, second segment with a single strong bristle, third segment 2½ times as long as broad; arista subpubescent. Palpus black, spatulate; theca slender, grey pollinose, weakly sclerotized.

Thorax.—Dark brown, not vittate. Acrostical bristles triserial, the middle row weak. Accessory setulae long, sparse. Prealars two, both strong. Stigmatal and mesopleural setulae numerous. Scutellum bare discally. Squamae pale yellow, margins more intensely yellowish, lower squama slightly projecting. Haltere deep yellow, wing membrane pale brown.

Abdomen.—1.8 by 3.2 mm. Bluish-grey-pollinose, with a dark brown, distinctly triangulated median vitta. Hypopygium moderately swollen.

Legs.—Black, not even knees yellowish. F_1 posteroventrals strong from base. T_1 without median bristles. F_2 anteroventrals with six strong bristles on basal half then three shorter, heavier bristles at two-thirds, and a preapical comb of 12-15 short bristles; posteroventrals stronger, more slender, less differentiated, weakly duplicated ventrally on median third. T_2 slender on basal half, then enlarging evenly to twice basal diameter, ventral mat sparse on basal half, half as long as tibial diameter on apical half, one anterodorsal, one posterodorsal. Mt_2 normal, unmodified. C_3 with one or two distinct posteroventral bristles. F_3 anteroventrals strong at base, decreasing toward apex, except for two widely-spaced, strong preapical bristles; posteroventrals setulose. T_3 with two anteroventrals,

about 10 anterodorsals on median three-fifths, and about 10 posteroventrals decreasing in size and length toward apex.

Hypopygium.—Cercal plate broad, short, with a single pair of strong apical bristles. Surstylus very broad on basal two-thirds, then suddenly constricted to narrow apex, basally narrowly confluent with ninth tergum and with three strong bristles near basal suture. Bacilliform process with only the dorsal process developed, very long and curved; ventral arm small and inconspicuous. Ninth sternum with strong lateroventral processes. Aedeagus distinctly sclerotized. Fifth sternum very broad with bristles strongly crowded toward posterior margin.

Female

Not known with certainty.

Type

Holotype.—♂, Yellow Dragon Gorge near Songpan (12-14000 ft.) 1924 (D. C. Graham) (U.S.N.M. No. 64541).

Remarks

A female from Mount Omei, Szechuen, China (11,000 ft.) 21.VII.1935 may be of this species but, as the legs are missing from the specimen, no definite determination can be made.

Fannia shinahamae, new species

This species belongs to the *hirticeps* group and is probably closely related to *cothurnata* Collin, *nidica* Collin, and *ungulata* Chillcott, but may be separated from these species by the presence of two anteroventral and three anterodorsal bristles on the hind tibia. Length 4.5 mm.

Male

Not as yet known.

Female

Head.—Parafrontals one-third as wide as long, greyish-brown-pollinose, separated by a black frontal vitta 1.5 times as wide as either parafrontal. Frontal bristles five, second and fourth strong. Lower orbital set on mid-line of parafrontal. Parafrontal setulae weak, in a single regular row. Parafacials narrow, slightly paler than parafrontals. Occipital bristles short, regular; postoccipital bristles in a single, usually complete row. Antenna black, second segment with single bristle, third segment slightly more than twice as long as broad; arista subpubescent. Palpus black, linear; theca glossy, swollen, as broad as long.

Thorax.—Bluish-brown-pollinose. Acrostical bristles biserial. Accessory setulae short, sparse. Stigmatal setulae one or two. Mesopleural setulae sparse, one or two bristles at anterodorsal corner strong. Scutellum with no accessory setulae. Squamae pale yellow, margins slightly darker, lower squama almost linear. Haltere clear yellow, wing pale brown, base yellowish.

Abdomen.—Dark bluish-brown-pollinose, subshining.

Legs.—F_1 posteroventrals strong, in a complete row. T_1 without median bristles. F_2 anteroventrals and posteroventrals setulose, except for one strong basal posteroventral bristle. T_2 with two anterodorsals, two posterodorsals. F_3 with one or two preapical anteroventrals strong. T_3 with one strong median and one weak preapical anteroventral, three anterodorsals.

Ovipositor.—Not dissected.

Type

Holotype.—♀, Shinahama, Japan, 1-4.VII.1954 (P. H. Arnaud) (U.S.N.M. No. 64542).

***Fannia tunisiae*, new species**

Figs. 2, 8

This species is very similar in general appearance to those of the *mutica* group but the absence of hind-coxal bristles and of a row of hind-tibial anterodorsals definitely places it in the *pretiosa* group. It can be separated from other members of the group by the numerous anteroventral and posteroventral bristles on the hind tibia. Length about 5.5 mm.

Male

Head.—Frontal bristles about 12, strong, extending almost to the ocellar triangle. Parafrontals narrow (0.03 increasing to 0.08 mm.), silvery-pollinose. Occipital bristles short, regular; postoccipital bristles absent dorsally. Antenna black, second segment with a single strong bristle, third segment 2½ times as long as broad; arista subpubescent. Palpus dark reddish-brown, subspatulate; theca lightly pollinose, weakly sclerotized.

Thorax.—Dark brown, not vittate. Acrosticals evenly triserial. Accessory setulae short, sparse. Prealars two, anterior one distinctly stronger. Stigmatal setulae two. Mesopleural setulae long, sparse, two or three distinctly stronger at anterodorsal corner. Scutellum normal. Squamae deep yellow, margins concolorous, lower squama distinctly projecting. Haltere deep yellow, wing membrane pale yellow-brown.

Abdomen.—2.0 by 3.5 mm. Grey-pollinose, median vitta distinctly triangulated, more or less surrounded by brownish pollinose area.

Legs.—Dark reddish-brown, knees paler. F_1 posteroventrals in a complete, regular row. T_1 without median bristles. F_2 anteroventrals strong at base, gradually decreasing in length apicad, blending evenly into preapical comb; posteroventrals similar, duplicated ventrally for most of length of femur. T_2 evenly and gradually increasing in diameter to apex, where it is twice basal diameter; ventral mat half as long as tibial diameter; one anterodorsal, one posterodorsal. C_3 bare posteroventrally. F_3 with full row of anteroventral bristles increasing in length to apex; posteroventrals numerous, hairlike, becoming longer apicad. T_3 with 10 long, bristlelike anteroventrals; three anterodorsals; numerous, hairlike posteroventrals and ventrals.

Hypopygium.—Very similar to that of *depressa* (Stein). Cercal plate slender, weakly elongate, not broadened apically. Surstylus simple, short, evenly tapering to apex. Bacilliform process distinctly spiralled. Fifth sternum strongly concave apically with lateral projections, bristles reduced, not scattered.

Female

Head.—Parafrontals one-fourth as broad as long, pale greyish-brown-pollinose; parafrontal setulae uniserial, few in number. Antenna and proboscis as in the male.

Thorax.—Paler than in the male with traces of vittae between the bristle rows. Squamae and wing paler in color.

Abdomen.—Dark bluish-brown-pollinose, not vittate.

Legs.—Color as in the male. F_1 posteroventrals weak basad. F_2 anteroventrals and posteroventrals setulose. F_3 with two strong preapical antero-

ventrals, setulose posteroventrals. T_3 with three anteroventrals, one or two anterodorsals.

Types

Holotype.– ♂, Kin Draham, Tunisia (no further data) (U.S.N.M. No. 64543).

Allotype.– ♀, same data as above (U.S.N.M.).

Paratypes.–2 ♀ ♀, same data as above (C.N.C. No. 7085).

***Fannia fuscinata*, new species**

Figs. 3, 9

This species is a member of the *kowarzi* group, but differs from its relatives in having only a single hind-tibial anteroventral bristle and distinctly more modified mid legs. In addition, the hind femur lacks the preapical posteroventral tufts and the hind-tibial posterior bristles are distinct and strong. Length about 6 mm.

Male

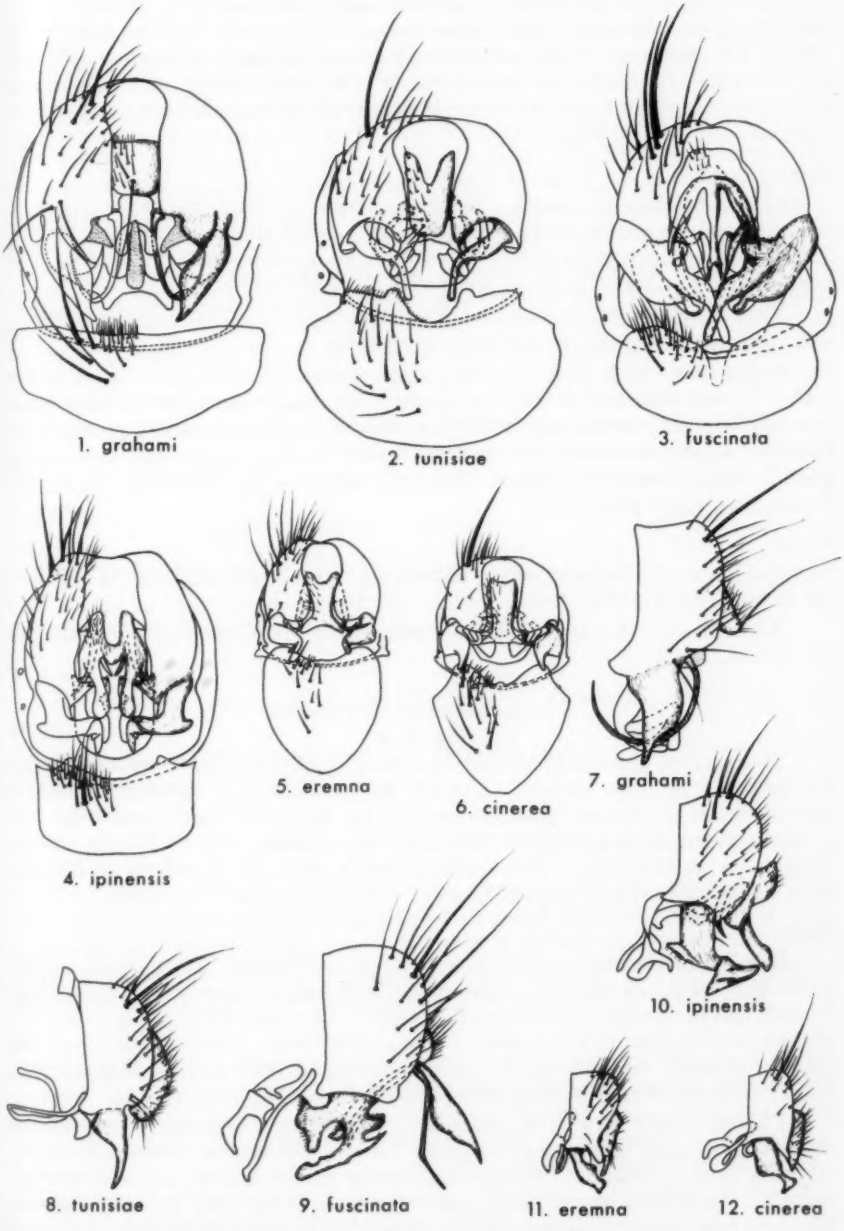
Head.–Frontal bristles 10-12, with several weak interstitials. Parafrontals broad (0.04 increasing to 0.16 mm.), silvery pollinose, separated by a black frontal vitta 0.06 mm. wide. Occipital bristles long, irregular. Postoccipital bristles in a full irregular row. Antenna black, second antennal segment with a single strong bristle, third antennal segment slightly more than twice as long as broad; arista distinctly thickened at base, subpubescent. Palpus black, linear; theca slender, subshining, weakly sclerotized.

Thorax.–Dark greyish-brown-pollinose, not vittate. Acrosticals triserial, the middle row weak. Accessory setulae moderate in number, strong. Prealars two, the anterior one stronger. Stigmatal setulae about eight. Mesopleural setulae moderate in number, distinctly stronger along dorsal margin. Scutellum bare medially. Squamae milky white, the lower distinctly projecting. Haltere yellow, wing membrane moderately infuscated.

Abdomen.–1.9 by 2.9 mm. Bluish-grey-pollinose, with distinct dark brown triangulated median vitta.

Legs.–Black, knees slightly paler. F_1 with a full row of posteroventrals. T_1 with one anterodorsal, one posterior. F_2 distinctly excavated preapically and ventrally; anteroventrals with about 10 strong bristles on basal half, then decreasing in length suddenly, with 10 shorter, closer-set bristles to three-fourths, a distinct break, and about six short bristles in a preapical comb; posteroventrals very strong and numerous, duplicated ventrally for entire length by almost equally strong bristles, a third ventral row visible on median third. T_2 expanding evenly to apex, distinctly glossy ventrally on basal half; ventral mat distinct only on apical half, as long as tibial diameter. Mt_2 with a weak basal clump of bristles at base. T_3 bare posteroventrally. F_3 anteroventrals as short but distinct setulae except for two strong bristles preapically; posteroventrals long and hair-like on basal two-thirds, short and setulose on apical third, not forming a distinct tuft. T_3 with one anteroventral, one strong and two or three weaker anterodorsals, five to seven posteriors on median third.

Hypopygium.–Strikingly modified, with numerous processes. Cercal plate elaborate, dorsally with a long median filament furcate at apex, and with broad lateral elements; lateroventrally with one strong process curving suddenly inwards, and a second process curving more ventrad with small setulae at apex. Surstylus also strikingly modified, dorsally with a rounded flap-like process at base bearing numerous short spinules; followed immediately by a short, sharp



Figs. 1-12. *Fannia* spp., male terminalia. 1-6, hypopygia, fifth sternite, and composite segment, posteroventral views; 7-12, hypopygia, left lateral views.

process curved basally; continued to apex as a slender but rather irregular portion; ventrally with a process which is narrow basally, then suddenly expanded to a wide apical portion which bears on its inner side numerous setulae. Bacilliform process not apparent. Ninth sternum well developed, the lateral arms supported by a thickened, heavily sclerotized rod on the inner margin. Fifth sternum distinctly wider than long with numerous short bristles crowded toward posterior margin.

Female

Head.—Parafrontals broad, one-third as broad as long, distinctly closer to upper orbital than usual, three strong and three weak alternating frontal bristles. Parafrontal setulae sparse, only two or three below lower orbital, postoccipital row complete. Antenna, theca, and palpus as in the male.

Thorax.—As in the male, with faint traces of vittae between bristle rows.

Abdomen.—Bluish-grey pollinose, not vittate.

Legs.—Color as in the male. F_1 posteroventrals in a full row. T_1 as in the male. F_2 anteroventrals weakly and scantily setulose; posteroventrals with a full row of hairlike setulae. C_2 with two anteroventral and two posteroventral bristles. F_3 anteroventrals and posteroventrals setulose except for two strong preapical anteroventrals on apical third. T_3 with one anteroventral, one anterodorsal, no distinct posteriors.

Types

Holotype.— ♂, Nagano, Pres., Karuizawa, Japan, 31.V.1953 (P. W. Oman) (U.S.N.M. No. 64544).

Allotype.— ♀, Kyoto, Vies., Kibune, Japan, 10.V.1953 (P. W. Oman) (U.S.N.M.).

Fannia ipinensis, new species

Figs. 4, 10

This species, like the preceding, is a member of the *kowarzi* group but can be distinguished from *kowarzi* (Verrall) by the lack of a hind-tibial posteroventral tuft of bristles, and from *fuscinata*, n. sp., by the distinctly golden-brown-pollinose parafrontals and parafacials and by the presence of two distinct anteroventrals on the hind tibia. This species is much more closely related to *kowarzi* than is *fuscinata*. Length about 5.5 mm.

Male

Head.—Frontal bristles about 10 with a few interstitials. Parafrontals narrow (0.04 increasing to 0.10 mm.), separated by a narrow black frontal vitta. Parafrontals and parafacials golden-brown in color. Occipital bristles long, irregular; postoccipital bristles in a complete, fairly regular row. Antenna black, second segment strongly bristled, third segment missing in both males. Palpus black, linear; theca slender, subshining, completely sclerotized.

Thorax.—Very dark brown in color, not vittate. Acrosticals triserial, the median row weak and rather irregular. Accessory setulae sparse and weak. Stigmatal setulae about 12. Mesopleural setulae numerous, only slightly stronger dorsally. Scutellum almost bare discally bearing only two pairs of bristles. Squamae pale yellow, margins slightly darker, lower squama weakly projecting. Haltere pale yellow, wing membrane very faintly infuscated.

Abdomen.—1.2 by 2.6 mm. Dark greyish-brown-pollinose, the dark brown median vitta weakly marked, weakly triangulated.

Legs.—Black, tibiae somewhat reddish in color, knees only slightly pale. F_1 with a full row of posteroventral bristles. T_1 without median bristles. F_2 anteroventrals with about eight short strong bristles on basal half, decreasing suddenly to closer-set bristles forming a comb preapically; posteroventrals longer, similarly differentiated, duplicated ventrally on basal half by short, strong bristles. T_2 evenly expanded to apex; ventral mat short and sparse on basal half, equal to tibial diameter on apical half; one anterodorsal, two posterodorsal bristles. Mt_2 with a short, inconspicuous basal clump of setulae. C_3 bare posteroventrally. F_3 anteroventrals setulose and prostrate, except for two strong bristles toward apex; posteroventrals setulose. T_3 with two anteroventral bristles, one anterodorsal, and a few, weak, suberect setulae on posterior surface medially.

Hypopygium.—Very similar to that of *kowarzi*, differing only in a few details. Cercal plate apically developed into two strong rounded lobes which are only slightly flattened laterally, lateroventral margins slightly extended. Surstylus broadly attached, only slightly articulated, weakly swollen on basal portion, bent sharply inward beyond the middle with a short outer process at bend, apex suddenly broadened to form a rather wrinkled truncate apex. Bacilliform process bifurcate at base, the dorsal process scimitar-shaped, curving outward; the ventral process similarly shaped, curving inward. Ninth sternum much broader than long, bristles crowded toward anterior margin, strong laterally.

Female

Not known with certainty. One female with the same data as the paratype male agrees in most characters, but the distinctly swollen theca and strictly biserial acrosticals suggest that it is another species.

Types

Holotype.—♂, Suifu, Szechuen, China (D. C. Graham). (U.S.N.M. No. 64545).

Paratype.—♂, Mt. Omei, Szechuen, China (11,000 ft.) 21.VII.1935 (D. C. Graham) (C.N.C. No. 7086).

***Fannia eremna*, new species**

Figs. 5, 11

This species is a member of the typical subgroup of the *serena* group. The very dark coloration and the linear parafrontals and parafacials separate it from all species of the *serena* subgroup. In general appearance the species comes closest to *parva* Stein, but the cercal plate of the hypopygium is distinctly different, and in general the coloration is much darker. Length about 5.2 mm.

Male

Head.—Frontal bristles 10-12, strong, without interstitials. Parafrontals very narrow (0.03 increasing to 0.04 mm.), almost contiguous. Parafrontals and parafacials darker brown-pollinose. Occipital bristles long, irregular; postoccipital bristles with one full and one partial row. Antenna black, second segment with one strong preapical and one shorter median bristle, third segment short, less than twice as long as broad; arista distinctly pubescent. Palpus subspatulate; theca subshining, not swollen, weakly sclerotized.

Thorax.—Very dark brownish-black, not vittate. Acrosticals strictly biserial. Accessory setulae very short and sparse. Prealar bristles two, the anterior one stronger. Stigmatal setulae about 10, mesopleural setulae numerous,

slightly stronger dorsally. Scutellum with only one pair of discal bristles. Squamae dark brown, margins concolorous, lower squama linear. Haltere with stem medium brown, knob very dark brown. Wing moderately infuscated, distinctly darker along anterior margin.

Abdomen.—1.2 by 2.6 mm. Dark grey-brown-pollinose, dark brown median vitta distinctly triangulated.

Legs.—Black, not even the knees pale. F_1 posteroventrals in a full row of long strong bristles. T_1 without median bristles. F_2 anteroventrals with a few fine setulae at base, then five strong wide-spaced bristles to two-thirds, changing to shorter, closer-set bristles forming a preapical comb; posteroventrals similar, slightly longer and finer, weakly duplicated on median third ventrad. T_2 evenly but weakly enlarged toward apex, ventral mat sparse on basal half, becoming longer until equal to half tibial diameter on apical half; one anterodorsal, one posterodorsal, both long and strong. C_3 bare posteroventrally. F_3 anteroventrals setulose except for two or three strong preapical bristles; posteroventrals setulose basad, becoming long and fine at two-thirds, absent on apical third. T_3 with one anteroventral, one anterodorsal.

Hypopygium.—Cercal plate strongly broadened apically and truncate at apex. Surstylus very broad on basal half with a faint dorsal emargination, suddenly and strongly constricted at two-thirds, then broadened again to truncate apex. Bacilliform process distinct and spiralled. Ninth sternum simple. Fifth sternum distinctly longer than broad, with numerous scattered bristles which are very strong and short toward posterior margin.

Female

Head.—Parafrontals dark greyish-brown-pollinose, one-third as broad as long, separated by a black frontal vitta slightly wider than either parafrontal. Lower orbital set slightly toward outer margin. Frontal bristles six to eight in number, alternately strong and weak. Parafrontal setulae numerous, in one irregular row; parafacials greyish-brown, slightly golden in certain lights. Postoccipital bristles in a full row. Palpus weakly spatulate; theca glossy, swollen, distinctly sclerotized.

Thorax.—As in the male except as follows: squamae pale yellowish-white, margins yellow; haltere yellow, wing membrane distinctly infuscated.

Abdomen.—Dark brownish-black-pollinose, not vittate.

Legs.—As for other *serena* group females, T_2 with one anterodorsal, one posterodorsal. F_2 with two or three strong preapical anteroventrals. T_3 with one anteroventral, one anterodorsal.

Types

Holotype.—♂, Mount Omei, Szechuen, China (11,000 ft.) 21.VII.1935 (D. C. Graham) (U.S.N.M. No. 64546).

Allotype.—♀, same data (U.S.N.M.).

Paratype.—♂, same data (C.N.C. No. 7087).

Fannia cinerea, new species

Figs. 6, 12

This species is very similar to *eremna*, n. sp., described above, differing from it mainly by the pale grey parafrontals and greyish-brown thorax and abdomen. It would key to *serena* (Fallén) in existing keys but differs from that species in that the thorax is more greyish, the female parafrontal and abdominal pollinosity is much denser, and the surstylus of the male hypopygium is distinctly narrowed at base. Length about 5.0 mm.

Male

Head.—Frontal bristles about eight, strong, with no interstitials. Parafrontals narrow (0.04 increasing to 0.06 mm.), silvery-pollinose, separated by a narrow black frontal vitta. Occipital bristles long, slender, very irregular. Postoccipital bristles in an irregular row usually extending almost to vertex. Antenna black, second segment with a single strong bristle, third segment twice as long as broad; arista subpubescent. Palpus linear; theca very slender, pollinose, moderately sclerotized.

Thorax.—Strongly greased in the only specimen available to me, but pleurae bluish-grey, dorsum probably dark greyish-brown. Acrostical bristles biserial. Accessory setulae short, sparse. Prealar bristles two, the anterior one stronger. Stigmatal setulae two or three. Mesopleural setulae sparse, scarcely stronger dorsad. Scutellum mostly bare discally. Squamae pale yellow, margins slightly darker, lower squama linear. Haltere medium yellow, wing membrane pale yellowish-brown, base of wing distinctly yellowish.

Abdomen.—Strongly curled in specimen before me so that exact measurements are not possible. Pollinosity and median vitta obscured by greased surface.

Legs.—Black, the knees scarcely paler. F_1 posteroventrals weak at base, quite strong on apical half. T_1 without distinct median bristles. F_2 with six to eight distinct bristles on basal half, becoming shorter on apical half and forming a short comb preapically; posteroventrals long and strong on basal two-thirds, weakly duplicated ventrad on median third, preapically with a short comb. T_2 scarcely expanded toward apex; ventral mat short but distinct on basal half, as long as tibial diameter and quite distinct on apical half. Mt_2 unmodified. C_3 bare posteroventrally. F_3 anteroventrals distinct and erect but short, with two or three strong bristles preapically, posteroventrals setulose. T_3 with one anteroventral, one anterodorsal.

Hypopygium.—Typical of the *serena* complex. Cercal plate preapically constricted, then broadened to form a truncate or slightly concave apex. Surstylus distinctly narrowed subbasally with a median dorsal expansion, apex only weakly broadened. Bacilliform process spiralled. Ninth sternum simple. Fifth sternum distinctly longer than broad, bristles sparse, slightly stronger and closer-set toward posterior margin.

Female

Very similar to the female of *eremna*, differing only in that the parafacials are silvery rather than golden-brownish and the postoccipital bristles are much sparser, not forming a complete row to vertex.

Types

Holotype.—♂, Mt. Omei, Szechuen, China (11,000 ft.) 21.VII.1935 (D. C. Graham) (U.S.N.M. No. 64547).

Allotype.—♀, same data (U.S.N.M.).

Paratypes.—2 ♀ ♀, same data (C.N.C. No. 7088).

Fannia indica, new species

This species belongs to the *canicularis* subgroup of the *canicularis* group and is closely related to the Oriental species *prisca* Stein, from which it differs in that the thorax and abdomen are brownish- rather than grey-pollinose, and the

median abdominal vitta is triangulated rather than parallel-sided. From *canicularis*, to which it will run in existing keys, it differs in that the parafrontals are narrow, the parafacials are haired in the male, the thorax lacks dorsal vittae, and the abdomen shows no trace of yellow basad. Length 5.5-6.0 mm.

Male

Head.—Frontal bristles 10 to 12, strong, with no or very few intermediates, extending almost to the distinct upper orbital situated just in front of the ocellar triangle. Parafrontals narrow (0.04 increasing to 0.10 mm.), brownish near ocellar triangle, silvery next antennae, separated by a black frontal vitta narrower than either parafrontal. Parafacials silvery, usually with two or three small setulae opposite the base of the arista. Antenna black, second segment with a single strong bristle, third segment twice as long as broad; arista subpubescent. Palpus linear; theca weakly pollinose, slender, weakly sclerotized.

Thorax.—Medium greyish-brown-pollinose, without distinct vittae. Acrosticals evenly triserial. Accessory setulae weak and sparse. Prealars two, anterior one distinctly stronger. Stigmatal setulae three or four. Mesopleural setulae sparse, moderately long, slightly stronger dorsad. Scutellum without median discal bristles. Squamae whitish, margins pale yellow, lower squama distinctly projecting. Haltere medium yellow, wing membrane only faintly infuscated.

Abdomen.—1.4 by 2.8 mm. Brownish-grey-pollinose, dark brown median vitta weakly expanded at posterior margins of segments. Hypopygium inconspicuous.

Legs.—F_1 posteroventrals as a full row of strong bristles. T_1 without median bristles. F_2 anteroventrals short but strong on basal half, gradually becoming shorter and closer-set toward apex, apical comb weak and setulose; posteroventrals longer and stronger, duplicated ventrally by a row of short weak bristles. T_2 weakly expanded toward apex; ventral mat distinct throughout, slightly longer and denser on apical half, at most equal to half tibial diameter; one anterodorsal, one posterodorsal bristle. C_3 with two or three distinct posteroventral bristles. F_3 anteroventrals with short, even bristles on basal two-thirds, with four or five strong bristles on apical third; posteroventrals in a full row, long and slender medially, at most equal to femoral diameter, preapically short and weak. T_3 with two anteroventrals, one strong and six to eight weak anterodorsals, no posterior or posteroventral bristles.

Hypopygium.—Almost indistinguishable from that of *canicularis*.

Female.

Not known.

Types

Holotype.—♂, Kodaikanal, Pulney Hills (6500 ft.), South India, April, 1953 (P. S. Nathan) (C.N.C. No. 6805).

Paratypes.—2 ♂ ♂, same data as holotype (C.N.C., U.S.N.M.).

Summary

Ten new species of *Fannia* are described. Six are from the China-Tibet border, two from Japan, one from Tunisia, and one from India. The male terminalia of six species are figured.

This brings to twenty the list of recorded species from the eastern Palearctic region.

(Received December 5, 1959)

The Effectiveness of Residues of Insecticides in Preventing Reinfestation of Apple Leaves by Apple Aphid, *Aphis pomi* DeG. I. Diazinon, Trithion and Sevin[1]

By D. P. Pielou and K. Williams[2]

Research Station, Research Branch, Canada Department of Agriculture
Summerland, British Columbia

Introduction

The apple aphid, *Aphis pomi* DeG., has long been a problem in British Columbia orchards (13), but has become particularly serious in the last few years (14, 15). Infestations are common on both bearing and young trees. Aphids occur especially at the terminal parts of new growth, suckers and sprouts. They reproduce extremely rapidly and large numbers cause curling and deformation of leaves. Further, this distortion of the leaves then protects the aphid colonies from spray application to some extent, and in clumps of such leaves, unharmed survivors are often found after the most thorough spraying. However, even where efficient spray application has been made before the leaf-curling stage has been reached, reinfestation and recolonization, presumably from outside sources, is a common occurrence. A search for "persistent" aphicides, that would at the same time give control of other common orchard pests such as codling moth, has been in progress at this laboratory for some years and in particular, Diazinon (15), Trithion (14), and Sevin (6) have been studied.

In this paper an attempt is made to compare the persistent effect of these three materials. Although claims for persistent effect in aphicides may be based on the presence, demonstrated chemically, of a material some days after application, in fact, the residue may be too little at this stage to be of use, or it may have altered chemically or physically to an innocuous form. Alternately, prolonged absence of aphids following application of insecticides may be due to very effective initial kill with a subsequent absence of invaders; in fact, no residual deposit at all may be present. A true persistent effect of an insecticide against aphids can only be demonstrated if invaders are given the opportunity of reinfesting trees that have been sprayed some time previously, and the trees checked, at that time, to see that none of the original population survived as possible progenitors. The tendency of aphids to produce leaf deformation that acts as a shield against insecticide sprays makes such extinction difficult.

Methods

Orchard Conditions

The experiments were carried out in an orchard of dwarf apple trees (on Malling IX rootstock) planted in rows 10 feet apart and running east and west. Trees were five feet apart in the rows. Two rows (varieties: Golden Delicious and McIntosh) were kept free of aphids up to the time of the experiment by repeated spraying with nicotine. Alternate rows were left untreated as a source of infestation, and a high population of aphids developed on these. Randomized plots of the *aphid-free* trees were sprayed in early July with the experimental materials. For each treatment there were three trees per plot and two plot replications for each variety. During the period of the 1957 trials the mean maximum and mean minimum temperatures were 78.4°F. and 53.9°F. respectively; in 1958 the corresponding temperatures were 87.5°F. and 60.3°F. These temperatures were taken in a standard Stevenson screen approximately 25 yards from the

1 Contribution No. 39, Research Station, Research Branch, Canada Department of Agriculture, Summerland, British Columbia.
2 Entomologist and Chemist respectively.

boundary of the orchard; the height of thermometers in such a screen is approximately the same as most of the twig-colonies of aphids that were studied on the dwarf trees. In 1957 there was an average rainfall of 0.030 inch per day during the experiments, in 1958 an average of 0.011 inch.

Assessment of Aphid Populations

On each tree five twigs were selected, and each twig tagged. The terminal bud of small partly-developed leaves was nipped off each twig. The five leaves immediately below on each twig were designated as Nos. 1 to 5. Subsequent to the application of spray, each of these leaves on each twig on all the trees of all the plots was inspected at intervals and the number of winged aphids – and later their wingless offspring – were counted. The counting of aphids on all the 6,000 leaves was repeated several times within a period of 26 days in 1957, and in a period of 24 days in 1958. The reason for nipping off the terminal bud was that these tiny leaves would develop rapidly within the test period and, because of this growth, would provide a surface largely free of the original deposit, and this fact might obscure any conclusions regarding the true persistence of the deposit. On the other hand, from the practical point of view, the removal of such ideal aphid-breeding foliage would tend to preclude any commercially useful assessment of the materials. Therefore, at the conclusion of the experiment, a separate assessment was made in which this factor was taken into account. A separate group of six normal twigs was picked at random per tree; the terminal bud, together with the five fully developed leaves below it, were removed from each twig and placed in jars of 50 per cent alcohol. Later the very large numbers of aphids (over 180,000 specimens) in these collections were separated out and counted with the aid of a suction device.

Materials Used

The insecticides used were Diazinon[2] [*O,O*-diethyl *O*-(2-isopropyl-4-methyl-6-pyrimidyl) phosphorothioate], Trithion[3] [*O,O*-diethyl *S*-(*p*-chlorophenylthiomethyl) phosphorodithioate] and Sevin[4] [1-naphthyl *N*-methylcarbamate].

The first two were supplied as 25 per cent wettable powders (7, 17), the third as a 50 per cent wettable powder (19).

Chemical Analysis of Deposits

The first chemical determinations of residues were made immediately after the newly applied insecticides were dry. Fifteen leaves (not those used for any insect observations) were picked from the trees on each plot, for each determination. From these 15 leaves, 50 discs of 1 cm. radius were cut with a cork borer. These discs comprised a foliage sample of known area for analysis. From each sample the insecticide was removed with 50 ml. of stripping solvent; the solvent was *n*-hexane for Diazinon and Trithion, and was chloroform for Sevin. Aliquots of the stripping solution were analysed by colorimetric methods. These methods are based on the hydrolysis of Diazinon to inorganic phosphate (8), of Sevin to l-naphthol (11, 12) and of Trithion to *p*-chlorothiophenol (18). Since the experimental trees received only the treatments described, there is no possibility that these breakdown products may have arisen from other sources.

Insecticide Application

Insecticides were applied to the experimental plots, which had been kept free of aphids by fumigation up to the commencement of the experiment, at a time

2 Geigy Agricultural Chemicals, New York, N.Y.
3 Stauffer Chemical Company, Mountain View, California.
4 Union Carbide Chemicals Company, White Plains, N.Y.

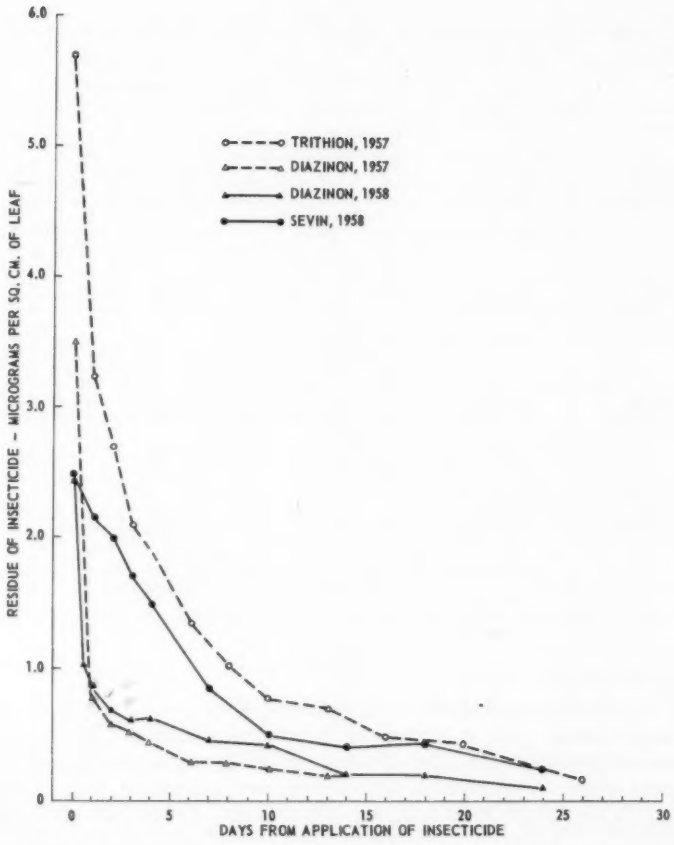


Fig. 1. Decline of residues of aphicides; concentration of spray-fluids, 0.05 per cent of active ingredient.

when the winged forms of the aphids had become so numerous on the adjoining trees that conditions for infestation of the experimental trees were ideal. In 1957 application of insecticides was made on July 17 and in 1958 on July 7. The materials were applied with a barrel-pump-sprayer at an average pressure of 110 lb. per sq. in. and approximately three gallons of spray mixture were applied per tree; for the dwarf trees this represented very thorough application. In 1957 Trithion and Diazinon were applied at the rates of 1 and 2 lb. of wettable powder per 100 gallons (i.e., concentration of active ingredient 0.025 per cent and 0.05 per cent respectively); in 1958 Diazinon was applied at 2 lb. per 100 gallons, and Sevin at 1 and 2 lb. (concentration of active ingredients 0.05 per cent and 0.1 per cent respectively). Treatments, including the controls that received no experimental insecticide but which had also been kept free of aphids with nicotine up to the commencement of the experiments, were replicated twice for each variety. Spraying was carried out in as nearly windless conditions as possible. While applications were being made each plot was isolated on three sides, including the windward side, by large mobile baffles made of aluminum sheeting; these baffles prevented spray drift to other plots.

TABLE I
Trithion and Diazinon residues on apple foliage, 1957. (Micrograms per sq. cm.)

Material and rate	Rep.	Tree variety	Days after application											
			0	1	2	3	4	6	8	10	13	16	20	27
Trithion 25% wettable powder	1	Golden	1.9	0.9	1.0	0.7	0.6	0.5	0.4	0.3	0.1	0.1	0.1	0.1
	2	Delicious	2.3	1.1	1.1	0.6	0.6	0.5	0.4	0.3	0.3	0.2	0.2	0.1
1 lb. per 100 gal.	1	McIntosh	2.7	2.5	2.0	1.7	1.7	0.8	0.8	0.8	0.6	0.3	0.3	0.1
	2		2.5	1.4	1.4	1.5	0.7	0.6	0.6	0.5	0.5	0.3	0.3	0.1
Trithion 25% wettable powder	1	Golden	5.3	2.2	2.1	1.5	1.4	1.0	0.6	0.6	0.4	0.3	0.3	0.2
	2	Delicious	4.5	2.0	1.7	1.5	1.3	0.9	0.6	0.6	0.5	0.3	0.3	0.1
2 lb. per 100 gal.	1	McIntosh	7.6	5.3	4.3	2.6	3.0	2.1	1.9	1.4	1.1	0.6	0.6	0.2
	2		5.4	3.5	2.6	2.7	1.9	1.4	1.0	0.5	0.8	0.5	0.4	0.1
Diazinon 25% wettable powder	1	Golden	0.5	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
	2	Delicious	1.0	0.2	0.3	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	
1 lb. per 100 gal.	1	McIntosh	1.9	0.5	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	
	2		1.2	0.4	0.2	0.3	0.2	0.1	0.2	0.2	0.2	0.2	0.2	
Diazinon 25% wettable powder	1	Golden	2.2	0.3	0.3	0.3	0.1	0.2	0.2	0.2	0.2	0.1	0.1	
	2	Delicious	3.4	0.4	0.4	0.4	0.3	0.2	0.3	0.1	0.1	0.1	0.1	
2 lb. per 100 gal.	1	McIntosh	3.1	1.2	0.9	0.7	0.6	0.4	0.4	0.4	0.3	0.2	0.3	
	2		5.3	1.2	0.7	0.7	0.7	0.4	0.3	0.3	0.2	0.3	0.2	

Results

Chemical Residues

Fig. 1 summarizes the data on the amounts of insecticide found on the leaves of the experimental trees at various times after application. Each point is the mean for both varieties and all replicates. In order to avoid confusion to graph shows only those concentrations that are exactly equivalent, i.e., Diazinon and Trithion at 2 lb. and Sevin at 1 lb. per 100 gallons. Other data are presented in

TABLE II
Diazinon and Sevin residues on apple foliage, 1958. (Micrograms per sq. cm.)

Material and rate	Rep.	Tree variety	Days after application										
			0	½	1	2	3	4	7	10	14	18	24
Diazinon 25% wettable powder	1	Golden	1.9	0.1	0.9	0.7	0.5	0.7	0.5	0.4	0.2	0.2	0.1
	2	Delicious	1.5	1.4	0.8	0.7	0.5	0.5	0.4	0.4	0.2	0.2	0.1
2 lb. per 100 gal.	1	McIntosh	4.4	1.6	1.0	0.8	0.9	0.7	0.6	0.6	0.3	0.2	0.1
	2		1.8	1.0	0.7	0.5	0.5	0.6	0.3	0.3	0.1	0.2	0.1
Sevin 50% wettable powder	1	Golden	2.2	—	2.0	1.6	1.5	1.4	0.8	0.3	0.3	0.2	0.1
	2	Delicious	2.6	—	2.8	2.5	1.8	1.5	1.0	0.5	0.3	0.3	0.2
1 lb. per 100 gal.	1	McIntosh	2.2	—	1.7	1.5	1.4	1.2	0.7	0.4	0.4	0.4	0.2
	2		2.6	—	2.1	2.4	2.1	1.9	0.9	0.8	0.6	0.8	0.4
Sevin 50% wettable powder	1	Golden	5.3	—	4.1	3.9	2.9	2.9	1.7	1.5	0.5	0.6	0.3
	2	Delicious	3.6	—	3.1	2.9	3.6	2.6	1.5	1.4	0.4	0.5	0.2
2 lb. per 100 gal.	1	McIntosh	4.3	—	3.0	3.2	3.0	2.6	1.4	1.5	0.9	0.9	0.6
	2		3.2	—	2.9	2.5	2.5	2.4	1.1	0.9	0.7	0.7	0.4

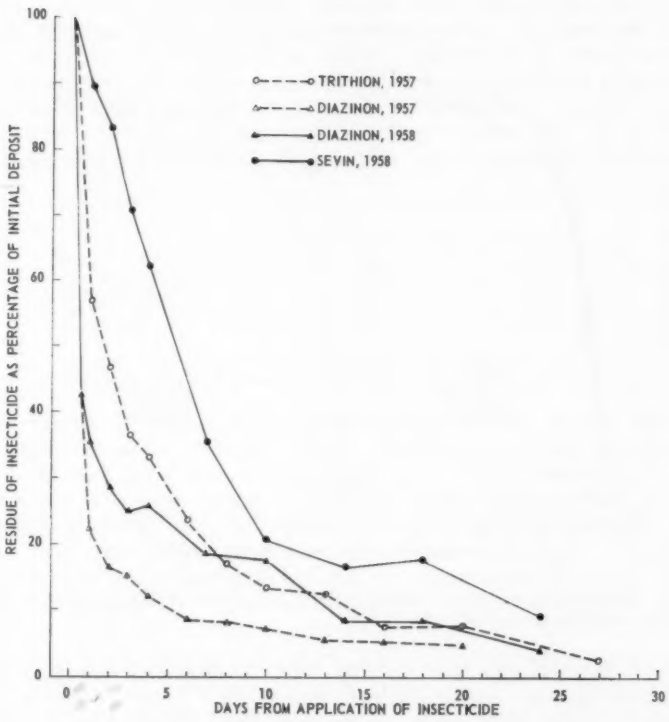


Fig. 2. Decline of residues of aphicides, plotted as a percentage of initial deposits.

Tables I and II where the values for individual replicates and separate varieties are shown. Examination of Fig. 1 and Tables I and II shows that deposits of Trithion are much higher than those of the other two materials. This is surmised as the result of superior formulation of this material. In order to eliminate the factor of variable size of the initial deposit the residue determinations have also been graphed as a percentage of initial deposit. The results for spray concentrations of 0.05 per cent are shown in Fig. 2. Sevin is clearly the most persistent material and Diazinon the least. There is some difference in the figures obtained with Diazinon in the two years that is not easily explicable, since temperatures were higher in the year when persistence was better; but in both cases the decline in deposit recoverable from the foliage is more rapid than that for Trithion and Sevin. From Fig. 2 we may say that the half-life of Diazinon on apple leaves is approximately 0.5 day, of Trithion 1.8 days and of Sevin 5.5 days.

Recolonization by Aphids

The aphids on the uppermost five leaves were counted at intervals during the period of the experiment. In 1957 counts were made 3, 5, 9 and 14 days after the application of spray material. In 1958 counts were made 3, 7, 14, 17 and 22 days after application. At the earlier dates it was possible to count all the aphids on a leaf with reasonable accuracy. Tests showed that there was no error up to 40 aphids per leaf, an error of $\pm$ 3 up to 70 per leaf and an error of $\pm$ 6 up to 100 per leaf. Above 100 per leaf aphids were estimated by counting the number in

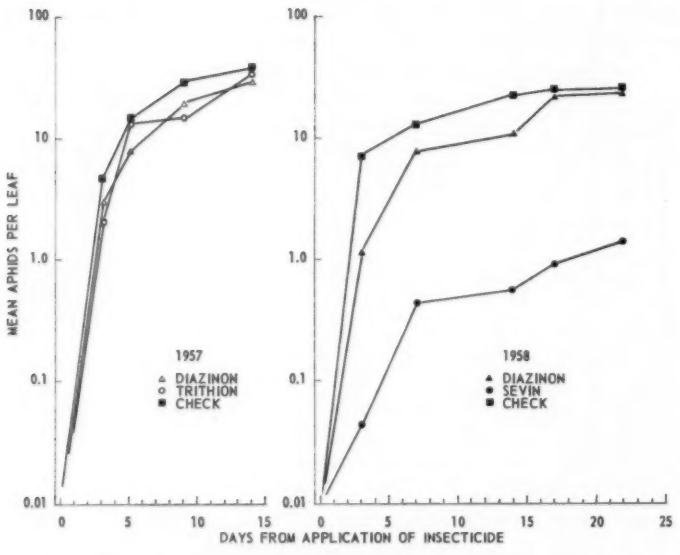


Fig. 3. Colonization of trees, originally aphid-free, from nearby sources of infestation, under various conditions of aphicide deposit.

one part of the leaf and then judging what fraction this was of the whole population on the leaf. Aphids on both sides of the leaf were counted. Though there were generally more aphids on the more distal leaves of the group of five inspected on each twig, figures were pooled to get a mean value per leaf. The results are shown in Fig. 3 for the equivalent concentrations of the three insecticides (0.05 per cent active ingredient), where each point is a mean obtained from observations on 300 leaves (five leaves per twig, five twigs per tree, three trees per plot, two varieties, two plot replicates). A logarithmic scale is used on the ordinates in Fig. 3 to cope with the wide range of insect densities. It will be seen from Fig. 3 (left, 1957 trials) that aphid numbers built up almost as rapidly on the Diazinon and Trithion plots as on the checks, and the differences between the three treatments were found (after transformation to a logarithmic scale to satisfy the conditions for analysis of variance) to be not significant ($P>0.05$) at any point. In Fig. 3 (right, 1958 trials) the difference between the checks and Diazinon was significant only at three days after application, but not at any other time. However, the difference between the checks and Sevin was highly significant ($P>0.01$) up to 22 days after application; and for 17 days the mean number of aphids was less than one per leaf. After 22 days the numbers of aphids increased rapidly with all treatments. The graph of the 1958 results in Fig. 3 gives the impression of a levelling off a numbers after 22 days; actually the graph is terminated at this point because the numbers of aphids per leaf became too large for accurate estimation by direct counts in the field. However, the populations on the Sevin-treated trees continued to be obviously lower than the others, a fact corroborated by the results of the following separate experiments.

The foregoing results apply to those twigs that had had the growing terminal bud removed. However, the leaf samples from the normal twigs were taken shortly after the conclusion of the experiment (27 days after spray application)

and were examined independently. Samples were taken from all plots (five leaves and terminal bud per twig, six twigs per tree, three trees per plot, two varieties, two plot replicates). The aphids collected from these leaves were counted accurately (see section on methods) at even the highest densities. The mean number of aphids per leaf (counting the terminal bud as one leaf) are shown in the following table for the two varieties of apple used. This series of experiments was carried out only in 1959, so no data are available for Trithion.

	Golden Delicious	McIntosh
Checks — no treatment	126.0	97.9
Diazinon 2 lb.	120.9	90.1
Sevin 1 lb.	27.5**	27.0**
Sevin 2 lb.	22.1**	25.6**

**Highly significant reduction ($P>0.01$) over check.

The numbers of aphids on the Diazinon-treated leaves are not significantly different from those on untreated leaves. However, reduction of numbers on leaves treated with Sevin is highly significant after 27 days although numbers per leaf now become so high as not to constitute commercial control. It must be remembered, however, that the constant presence of entire alternate rows of untreated trees, only 10 feet away from the experimental rows, constituted very severe conditions for reinfestation and put the experimental materials to a maximum test. Taking the two series of experiments into consideration it is evident that Sevin at either one, or two, pounds of the 50 per cent wettable powder per 100 gallons, gave commercial control for two to three weeks against *reinvading aphids* (no evidence is presented on the direct effect of Sevin on the initial resident population) and a significant reduction for up to four weeks following application even where conditions for recolonization were very favorable.

Discussion

The rapid decline of insecticidal effectiveness of many insecticides after they have been applied to foliage constitutes an important and often puzzling problem in applied entomology. There are many situations where a lasting effectiveness is desired but where otherwise desirable materials show a lack of persistence, but do not do so when applied to, say, the interior walls of farm buildings. The circumstances that determine the deposition, accumulation, adhesion, persistence and chemical stability of insecticides on foliage are complex. Work on some of these factors has recently been summarized by David (4) who emphasizes that the causes of the rapid decline, weathering and breakdown of insecticides in the open, and on foliage, have been comparatively little investigated, though, from the practical point of view, any means of reducing such losses would be very valuable. David defines the *tenacity* of the initial deposits as the ratio of a given amount of residue at a given time to its initial level. However, the residue may be a breakdown product of the original material that the chemical method of analysis is unable to distinguish; the material may have changed to some different and relatively inert physical form, or may have been incorporated within part of the leaf (9). Consequently, tenacity may not be a measure of entomological effectiveness.

In our experiments we have confined ourselves to the limited objective of examining three insecticides, and attempting to correlate the amount of residue chemically detectable after several days with the entomological effectiveness of

the deposit. In view of the present laws in Canada (1) and the United States (16) on pesticide residues on fruit, the importance of the presence of detectable amounts of insecticides, sufficient to cause legal concern but insufficient to be effective, is obvious. At times materials are wanted that have a short life and no detectable residue after a brief period; at other times materials with a long effective residual action are desired. The transient effectiveness of Diazinon is not surprising in view of the brief life of the material demonstrated chemically. The long residual 'tail' of Trithion is, however, ineffective as far as aphids are concerned, and is, therefore, only a nuisance from a regulatory point of view. However, in other experiments (5) it has been shown that Trithion residues after more than seven days are toxic to the young proto-nymphs emerging from the eggs of the European red mite, *Panonychus* (= *Metatetranychus*) *ulmi* (Koch), at least where local strains of this species are not resistant to organic-phosphate pesticides in general.

From the data presented in this paper, Sevin appears in the most favorable light. It is known that this material 'weathers' relatively well in the presence of rain and light (10). However, other factors have to be taken into account when making an assessment of the material. Reports from orchardists in 1959 suggested that, in some areas, it was less effective, in the rapidity of its initial kill, than were the organic-phosphates, though the persistence of its residue was not questioned. But, more serious, Sevin appeared to cause apple-drop if applied too soon after the blossom period; and its residual effect made it a moderately toxic bee-poison if applied one or two weeks before blossom. Accordingly the use of Sevin, as recommended in the 1959 spray calendar for British Columbia (2), has been somewhat restricted in the 1960 spray calendar (3). However, the efficiency of Sevin against DDT-resistant strains of codling moth, *Carpocapsa pomonella* (L.), and against several other common orchard pests in British Columbia (6), and its residual action against green aphid, make it likely that it will be a recommended material in this province for a considerable time.

Summary

The effectiveness of residues of insecticides in preventing reinfestation of apple foliage has been examined by spraying *aphid-free* trees with experimental materials, and observing the progress of colonization from nearby sources of infestation. In this way an estimate of true persistent effect was made unobscured by relative differences in initial kill. On aphid-free trees sprayed with Diazinon, which had a half-life of 0.5 day on apple leaves in our experiments, and with Trithion (half-life 1.8 days) recolonization of aphids was almost as rapid as on check plots. But with Sevin (half-life 5.5 days) aphids were kept at a commercially low level for 17 days and were still significantly fewer than on the check plots after 27 days. It was also noted that, for the same concentration of spray fluids, initial deposits, determined immediately after drying, were higher with Trithion; this appears to be the result of superior formulation, and the reputation of this material as an aphicide would seem to lie in its effectiveness in immediate kill on application.

References

(1) Altmark, M. G. 1958. Canadian views and policies on insecticide tolerances. *Proc. 10th Int. Congr. Ent., Montreal,* 1956, 3: 283-289.

(2) Anonymous. 1959. Control of tree-fruit pests and diseases. *British Columbia Dept. Agr. Poster.*

(3) Anonymous. 1960. Control of tree-fruit pests and diseases. *British Columbia Dept. Agr. Poster.*

(4) David, W. A. L. 1959. The accumulation and adhesion of insecticides on leaf surfaces. *Outlook on Agr.* 2: 127-136.

(5) Downing, R. S. 1958. Recent trials with new acaricides in British Columbia orchards. *Canadian J. Plant Sci.* 38: 61-66.
(6) Downing, R. S. 1959. Sevin as an orchard insecticide in British Columbia. *Proc. Ent. Soc. British Columbia* 56: 41-45.
(7) Geigy Agricultural Chemicals. 1956. Diazinon Tech. Bull. 56-1, New York, N.Y.
(8) Geigy Agricultural Chemicals. (No date). Methods of analysis for Diazinon. Bull. New York, N.Y.
(9) Gunther, F. A., and R. C. Blinn. 1956). Persisting insecticide residues in plant materials. *Ann. Rev. Ent.* 1: 167-180.
(10) Hightower, B. G. 1959. Bioassays of weathered residues of several organophosphorus insecticides. *J. Econ. Ent.* 52: 840-842.
(11) Miskus, R. 1957. Modification in the method of analysis for Sevin. Private communication.
(12) Miskus, R. 1957. Modification in the method of analysis for Sevin. Univ. California, Berkeley. Unpublished results. Private communication.
(13) Palmer, L. L. 1913. Some problems of aphis control. *Proc. Ent. Soc. British Columbia* 3: 31-34.
(14) Pielou, D. P., and R. S. Downing. 1958. Trithion as an orchard insecticide. *Proc. Ent. Soc. British Columbia* 55: 17-23.
(15) Pielou, D. P., and M. D. Proverbs. 1958. Diazinon: A summary of recent work on a new orchard insecticide. *Proc. Ent. Soc. British Columbia* 55: 3-6.
(16) Rankin, W. B. 1958. The establishment of pesticide tolerances in the United States. *Proc. 10th Int. Congr. Ent., Montreal, 1956*, 3: 269-272.
(17) Stauffer Chemical Company. 1956. Compound R-1303. Bull. Mountain View, California.
(18) Stauffer Chemical Company. 1956. Modification and additions to the "Colorimetric determination of R-1303 in plant material". Bull.
(19) Union Carbide Chemicals Company. 1958. Sevin insecticide. Bull. White Plains, N.Y.

(Received April 6, 1960)

Notes on the Life-History of the Onion Maggot, *Hylemya antiqua* (Meig.) (Diptera: Anthomyiidae) Reared in Field Cages

By J. P. Perron and J. Lafrance
Research Laboratory, Research Branch, Canada Department of Agriculture
St. Jean, Que.

The onion maggot, *Hylemya antiqua* (Meig), has three distinct generations a year in Canada (Armstrong 1924, Hammond 1924, Baker 1928, Lafrance and Perron 1959), and usually two generations in England (Miles 1955). In Canada the three generations overlap considerably and adults of each generation are observed in flight in late summer (Perron *et al.* 1953). It is the most important pest of onions (Matthewman *et al.* 1950, Hudon and Perron 1956), and the first generation is the most injurious to the onion plants (Kendall 1932, Miles 1953).

This is a report on experiments conducted in large field cages at St. Jean, Quebec, from 1953 to 1955, on the population increases, percentage pupae of each generation remaining dormant and longevity of adults in relation to field temperature and weather conditions in general.

Materials and Methods

Field investigations were conducted on each generation in rearing cages nine by nine by six feet and in composite emergence cages three by three by one feet (Lafrance and Perron 1955). In mid-May, when first adults appeared in the field, 50 males and 50 females, obtained from pupae stored at 35°F, were placed in one of the rearing cages to provide stages of the first-generation. The adults were fed on an artificial diet (Perron *et al.* 1953) and food was changed

TABLE I

Population increase, longevity of adults, number of eggs laid and per cent pupae dormant per generation of onion maggot *Hylemya antiqua* (Meig.) reared in large outdoor cages, and weather conditions, St. Jean, Quebec, 1953-1955.

Generation	Initial population of adults	Population at end of each generation	Adult Longevity		Eggs per females	Per cent pupae remaining dormant	Weather conditions		
			Period	Number of days			Daily Mean Temper.(°F.)		Precipitation
							Air	Soil	(Inches)
1953									
First	50 50	1239	May 17 to July 31	75	57.7	0.08	64.1	63.5	10.1
Second	50 50	2361	July 9 to Sept. 22	75	41.6	67.7	66.2	64.0	4.68
Third	50 50	210	Aug. 10 to Nov. 22	104	12.5	99.5	53.1		5.01
Mean				84.6			61.1	63.7	6.6
1954									
First	50 50	1299	May 26 to July 19	54	29.9	19.0	65.0	63.0	7.63
Second	50 50	2322	July 10 to Aug. 31	52	36.4	90.8	68.6	64.5	5.88
Third	50 50	775	Aug. 9 to Oct. 17	69	14.5	100.0	60.2	59.0	12.93
Mean				58.3			64.6	62.1	8.81

Mean				58.3			64.6	62.1	8.81

1955

First	50 50	2731	May 25 to July 10	46	85.8	0.0	69.6	70.0	3.29
Second	50 50	2859	July 15 to Sept. 2	49	30.8	43.5	75.2	70.0	7.05
Third	50 50	2192	Aug. 10 to Oct. 14	65	45.9	99.01	60.6	60.0	3.45
Mean				53.3			68.4	66.6	4.59

Means per generation from 1953 to 1955

First	50 50	1756			57.8	6.3	66.2		
Second	50 50	2514			36.2	67.5	70.0		
Third	50 50	1059			24.3	99.8	57.9		

twice a week and oftener in rainy weather. The females laid eggs on onion sets of the variety Ebenezer planted in flats 24 by 6 by 6 inches filled with muck soil and located in the rearing cage. The eggs were collected every second day, counted, and transferred to similar flats placed in an emergence cage and left there for the remainder of the summer. All adults emerging from the emergence cage were collected and counted. The flats used for egg deposition in the rearing cage were also transferred into the emergence cage after three weeks, to prevent any adult emergence in the former. In the fall, when adult emergence had ceased, the soil was removed from the flats, passed through a flotation separator (Lafrance and Perron 1956), and pupae recovered and per cent dormancy calculated. The same procedure was followed for the study of the second- and third-generation using first- and second-generation flies collected from emergence cages. Temperature and precipitation records were kept during the three-year period of study.

Results and Discussions

Population increase per generation. The highest increase in population was observed in the second generation and the lowest in the third. The mean population increase per generation from the initial population was 17.5 times for the first generation, 25.1 times for the second, and 10.5 times for the third. From early July to mid-August, i.e., during the period of the second generation, the soil and air temperatures were highest, this favouring hatching and larvel establishment, and increasing considerably populations of the second generation. Miles (1958) in laboratory tests, found that at 80°F the larval stage was reduced to nine days, at 68°F it lasted 14 days, and at 50°F, 40 days and more. In laboratory tests conducted at St. Jean, during a six-month period, one generation per month was obtained at 80°F (Perron *et al.* 1953).

Longevity of adults. The flies in the rearing cages lived, mated, and reproduced quite normally throughout the season. High temperature was unfavourable to adults and reduced their longevity by several days. In 1953, the coolest year, the mean longevity of females of all three generations was 84.6 days. In 1954, an average year, the mean was 58.3 days; in 1955, the warmest year, the mean was 53.3 days (Table I). In 1955, the males lived an average of 33 days and the females 53.3 days (Table II). Length of life of males and females were not calculated for 1953 and 1954. Males usually lived slightly less than two-third the life period of females. Perron *et al.* (1953) reported that adults, reared in the insectary and protected from direct sunlight, wind and rain, lived much longer, i.e., 139 days for females and 70 days for males. Soil temperatures and normal precipitation seem to have little or no influence on adult behaviour.

Number of eggs laid. The highest number of eggs was generally laid by adults of the first generation and lowest number by those of the third generation females; means for the three years were, 57.8 for the first, 36.2 for the second and 24.3 for the third generation (Table I). High temperatures caused premature death of adults and thus reduced the potential total egg deposition of females. This was particularly evident in 1955 when second-generation females averaged 30.8 eggs at a mean temperature of 75.2°F (Table I). Under insectary conditions (Perron *et al.* 1953) when adult life is not shortened by weather factors, a female may lay as many as 706 eggs. Oviposition decreased considerably in the third generation when mean temperatures did not exceed 57.9°F. In the field large numbers of eggs may also be washed or carried away by heavy rains and high winds.

TABLE II
Mortality Rate of *Hylemya antiqua* (Meig.) Adults for the Year 1955
St. Jean, Que.

Date	No. of days	Adults		Per cent alive	
		Males	Females	Males	Females
First Generation					
May 25	0	50	50	100.0	100.0
,, 31	6	25	32	50.0	64.0
June 16	22	1	26	2.0	52.0
,, 23	29*	0	23	0.0	46.0
,, 30	36	0	5	0.0	10.0
July 10	46**	0	0	0.0	0.0
Second Generation					
July 15	0	50	50	100.0	100.0
,, 26	11	11	26	22.0	52.0
Aug. 3	19	3	18	6.0	36.0
,, 12	28	1	13	2.0	26.0
,, 24	40*	0	4	0.0	8.0
Sept. 2	49**	0	0	0.0	0.0
Third Generation					
Aug. 10	0	50	50	100.0	100.0
,, 24	14	21	31	42.0	62.0
Sept. 2	23	3	26	6.0	52.0
,, 9	30*	0	18	0.0	36.0
,, 19	40	0	12	0.0	24.0
Oct. 3	54	0	2	0.0	4.0
,, 14	65**	0	0	0.0	0.0

* Life period of males – mean = 33.0 days.
** Life period of females – mean = 53.3 days.

Per cent pupae remaining dormant. Dormancy was observed in each generation and varied as follows: 0 to 19 per cent for the first generation, 43.5 to 90.8 for the second, and 99.1 to 100 for the third. In 1953 and 1954 the summer seasons were much cooler than in 1955, and a higher proportion of pupae remained dormant in the first two generations. Precipitation seems to have little influence on dormancy. The second generation is considered the most important of the three generations for species survival, having the highest increase in population and contributing the highest total number of overwintering pupae.

Summary

Onion maggot *Hylemya antiqua* (Meig.) investigations on the number of generations, longevity of adults, the population increase and the per cent pupae remaining dormant per generation were conducted at St. Jean, Que. in field rearing cages from 1953 to 1955. Longevity of adults and per cent of pupae remaining dormant at each generation depended mostly on temperature. Dormancy was observed in each generation, the highest being observed in the third generation. High temperature increased egg-laying, favoured larval establishment and shortened the larval period. The highest number of eggs were

laid by the first-generation females and the lowest by those of the third-generation. The highest increase in population was obtained in the second generation, which generation also contributed the greatest number of overwintering pupae.

References

Armstrong, T. 1924. Onion maggot studies in the district of Montreal, Quebec 1923. *Rep. Ent. Soc. Ont.* 1923. pp. 42-45.

Baker, A. D., and K. E. Stewart. 1928. The onion root-maggot (*Hylemya antiqua* (Meig.)) on the Island of Montreal. *Rep. Quebec Soc. Prot. Pl.* 1927-1928, pp. 92-138.

Hammond, G. H. 1924. The onion maggot in the Ottawa district. *Rep. Ent. Soc. Ont.* 1923, pp. 39-41.

Hudon, M., and J. P. Perron. 1956. Dipterous species infesting onions in the muckland areas of southwestern Quebec. *Rep. Quebec Eoc. Prot. Pl.* 1954, pp. 89-92.

Kendall, E. W. 1932. Notes on the onion maggot (*Hylemya antiqua* Meigen.)) *Rep. Ent. Soc. Ont.* 1931, pp. 82-84.

Lafrance, J., and J. P. Perron. 1959. Notes on the life-history of the onion maggot, (*Hylemya antiqua* (Meig.) (Diptera: Anthomyiidae), in sandy and organic soils. *Canad. Ent.* 91: 633-638.

Lafrance, J., and J. P. Perron. 1955. Composite emergence cage for studies on the life-history of the onion maggot (*Hylemya antiqua* (Mg.) (Diptera: Anthomyiidae). *Canad. Ent.* 87: 358-362.

Lafrance, J., and J. P. Perron. 1956. Flotation separator for collecting puparia of the onion maggot (*Hylemya antiqua* (Mg.) (Diptera: Anthomyiidae), from the soil. *Rep. Quebec Soc. Prot. Pl.* 1955, pp. 43-46.

Matthewman, W. G., A. W. Rathwell, and J. P. Lachaine. 1950. Notes on the species of root maggots damaging onions, cabbage and radish at Ottawa in 1948. *Canad. Ent.* 82: 12-16.

Miles, M. 1953. Studies of British anthomyiid flies. The onion fly, *Delia antiqua* (Mg.). *Bull. Ent. Res.* 44 (Part 3): 583-588.

Miles, M. 1955. Studies of British anthomyiid flies. The annual cycle of generations in some anthomyiid root flies. *Bull. Ent. Res.* 46. (Part 1): 11-19.

Miles, M. 1958. Studies of British anthomyiid flies. Biology of the onion fly, *Delia antiqua* (Mg.). *Bull. Ent. Res.* 49 (Part 2): 405-414.

Perron, J. P., J. Lafrance, and M. Hudon. 1953. Notes on the behaviour of the adults of the onion maggot, *Hylemya antiqua* (Meig.) in captivity. *Reps. Quebec Soc. Prot. Pl.* 32-33 (1950-51) pp. 144-148.

(Received April 6, 1960)

Coenonympha tullia on Islands in the St. Lawrence River

By F. Martin Brown
in collaboration with Bernard Heineman

The philosophy of subspeciation among animals requires that these taxa be essentially reproductively isolated. When such isolation does not exist clines appear. We believe that we have discovered one of the rare occasions when two well-defined subspecies, considered by some taxonomists to be two species, occupy the same terrain and where some degree of hybridization has taken place with the production of a hybrid brood that is temporally isolated from one subspecies and geographically from the other. Neither isolation may be absolute but that condition is closely approached.

Brown (1958) described a member of the superspecies *tullia* found on Picton and Grindstone Islands, near Clayton, New York, as *heinemani*. In the original description he pointed out that this taxon appears to be more closely related to *nipisiquit* McDunnough than to *inornata* Edwards and that like *nipisiquit* it is a late-summer butterfly. At the time that the type series was collected in August, 1957, Heineman agreed to search for *Coenonympha* on the islands in May and June. The next spring he was successful in finding butterflies of the genus on the islands and he was able to get eggs from both the spring and late-summer insects. The eggs were shipped by airmail to Brown for a study of the life-histories and especially to learn if the spring brood gave rise to the late summer brood.

From study of the immature stages we are now convinced that the May-June insect and the August-September insect (*heinemani*) are each single-brooded and do not give rise one to the other. This seems proof to us that we have two taxa temporally separated living in the same fields on these islands. From a study of series of the imagoes it is clearly evident that there has been a flow from the gene-pool of *heinemani* into the gene-pool of the spring insect. Such could happen only by occasional hybridization. The pattern of the life-histories of the two broods is such that hybridization must be rare. However the wide distribution of *heinemani* characteristics among the spring specimens suggests that it has been taking place over a considerable length of time. Reference to Fig. 1 will show that there is at least two months' interval when no *Coenonympha* are found flying on the islands. The larvae of *heinemani* hibernate as soon as they have emerged from the egg or at latest after the first moult. The spring butterflies produce larvae that hibernate in the fourth, and occasionally in the third instar, just as do the larvae of *inornata* in Quebec. To prevent cumbersome circumlocution in this article we will hereafter refer to the spring hybrid brood as "*inornata*", always using quotation marks with it.

Davenport (1941) briefly described the early stages of *inornata* from material he collected in Quebec. Since we have made rather detailed studies of these stages that amplify Davenport's notes we present our descriptions of the stages that we have observed, and compare the first two with those of *heinemani*. Studies of *Coenonympha ochracea* Edwards (=*phantasma* Burdick), native to Colorado, are under way. In the first two, but not later, instars larvae of *ochracea* show some slight differences from the eastern taxa. The differences are slight and only noticeable when the two larvae are examined alongside of one another under a binocular microscope. This confirms, in our opinion, the logic of considering the eastern and western material under consideration as representative of a single basic species. An article bringing together what is known of the life-histories of

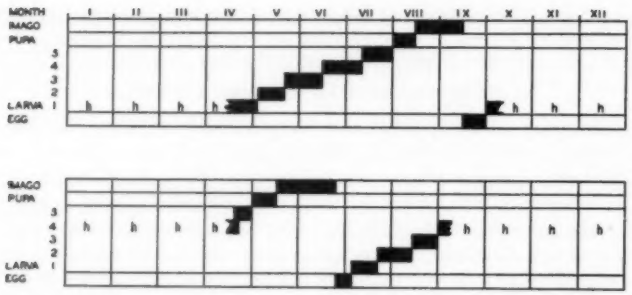


Fig. 1. Seasonal histories of *Coenonympha* populations on islands in the St. Lawrence River. Upper, *heinemani*, lower, "*inornata*".

North American *tullia* is in preparation and will in part be illustrated with photographs of living specimens.

The Early Stages of Thousand Islands "*inornata*"

Eggs

When first laid these are very pale green and immaculate. After three or four days they become straw yellow and are lightly mottled with narrow irregular patches of pinkish brown. They are somewhat barrel-shaped with the top a little less in diameter than the bottom. The sides are ridged with about 36 vertical ribs between which there are many transverse ridges breaking the surface into small quadrate depressions. The micropyle lies on a slightly mounded prominence and is surrounded by a broad zone stippled with very shallow, more or less round dimples. The maximum diameter of the egg is about 0.7 mm. and the maximum height about 0.9 mm.

When the eggs of *heinemani* are compared with those of "*inornata*" slight difference appear only in the proportions of the eggs. The eggs of *heinemani* are about the same diameter as those of "*inornata*" but are shorter, measuring 0.75 mm. by 0.71 mm. The coloring and sculpture seem to be identical.

First Instar

Just before the caterpillars emerge the eggs darken somewhat. The little caterpillars eat a hole in the top of the egg, completely removing the lid of the barrel. Occasionally all or most of the eggshell is eaten.

Upon emergence the caterpillar is almost white, just slightly tinged with straw. The head is a little darker than the body but soon it becomes noticeably so, a shade of brown that is slightly yellower than chestnut. As the caterpillar ages, but before it begins to feed, the longitudinal stripes, almost invisible upon emergence, darken. There are seven of these pinkish-brown stripes. The broadest is a mid-dorsal line, the others are lateral, three on a side. The most ventrad of these lies just above the line of the spiracles. It and the dorso-lateral line are bolder than the mid-lateral line which is slightly fragmented. A fine, barely visible pubescence covers the body and head. The caudal bifurcation is slightly brownish.

Feeding soon changes the color of the body to greenish. About the fifth day after emergence from the egg a rather broad white band develops ventrad of the lateral stripes, below the row of spiracles, and the dorsum becomes stippled with

white papillae. The broad white lateral band is coarsely and irregularly granular. The spiracles are in direct contact with the upper margin of the band. Davenport (*l.c.* p. 264) made no mention of the brownish lateral lines. We believe this was an oversight on his part.

Upon emergence the caterpillar is about 2.4 mm. long. The head is about 0.6 mm. in diameter and almost circular in front view. The thoracic segments are markedly less in diameter than is the head and the body tapers to the tail end.

The only differences we noted between the first instar larvae of "*inornata*" and *heinemani* are these: the emergent caterpillars of *heinemani* are smaller than those of "*inornata*", measuring only 1.65 mm. long by 0.52 mm.; the little brown lobes, pendent from the ventral lateral line and engulfing the spiracles, are a little more prominent on *heinemani* than on "*inornata*". The differences are far less conspicuous than between *inornata* and *ochracea* at the same stage of development.

Second Instar

The greatest change that takes place at the first moult is that the head changes in color from brown to green. The green head is noticeably stippled with white papilli and bears a few brownish marks at the mandibles. The ocelli are black. The dorsal and lateral reddish-brown stripes are about as they were in the first instar. The ventro-lateral whitish band is quite conspicuous. The dorsum is thickly stippled with tiny white papillae.

As the caterpillar ages in this instar the lateral lines tend to lose their reddish-brown color and assume a dark green one. The total length of the caterpillar before it starts feeding is about 3.6 mm. The head has a width close to 0.70 mm. and heighth of 0.77 mm.

The only difference that we can see between second-instar larvae of *heinemani* and "*inornata*" is that the heinemani caterpillars are smaller, only 3.0 mm. long after the moult.

Third Instar

This stage differs from the preceding one in these respects: The dorsal and lateral dark lines are barely noticeable; the first impression image is a pale-green caterpillar with longitudinal dark green stripes. Actually dark green is the body color and the broad areas stippled with tiny white papillae create the impression of light green. The mid-dorsal zone of dark green is quite broad, the three lateral lines are rather narrow. The ventrad whitish band is conspicuous.

Immediately after the moult and before feeding the caterpillar is 6.2 mm. long. The head is about 1.1 mm. high and 1.0 mm. wide.

Fourth Instar

There is no noticeable difference in the appearance of the caterpillars in this stage when compared with the previous one except in size. Before feeding the total length is 7.3 mm., the head is 1.3 mm. high and 1.25 mm. wide.

We have been repeatedly unsuccessful in carrying hibernating larvae through the winter. Modern refrigerators desiccate them. Colorado's climate in winter is so irregular that the eastern species come out of hibernation during the first warm period in January and then are killed by a freeze when they have been stored out-of-doors.

A timetable of moults for the thirteen caterpillars of "*inornata*" brought to hibernation in 1958 is:

No.	Hatched	1st moult	2nd moult	3rd moult	Hibernated
A	vii.5	vii.18	viii.3	viii.14	iv.7
B	vii.5	vii.18	viii.4	viii.20	viii.31
C	vii.5	vii.18	viii.7	—	viii.30
D	vii.5	vii.18	viii.5	viii.13	ix.1
E	vii.5	vii.18	viii.5	viii.19	viii.29
F	vii.5	vii.19	viii.3	viii.17	viii.30
G	vii.5	vii.19	viii.3	viii.21	ix.7
I	vii.5	vii.21	viii.7	viii.20	ix.4
J	vii.7	vii.19	viii.2	viii.19	ix.7
K	vii.7	vii.19	viii.6	—	viii.31
L	vii.7	vii.24	viii.7	viii.29	ix.3
M	vii.7	vii.24	viii.8	viii.29	ix.7
N	vii.7	vii.29	viii.8	viii.21	ix.2

The eggs of *heinemani* laid on September 2nd hatched on the 18th and the first moult was made by one caterpillar on October 3rd. Thus it is clear that *heinemani* and "*inornata*" hibernate at different points in their development.

In the case of "*inornata*" the duration of the instars progressively became more variable. The mean duration, standard deviation of the mean and the range for the three instars observed completely are:

Instar	*n*	*means days*	*range*
First	12	14.0 ± 1.6	12 to 17 days
Second	12	16.3 ± 1.9	14 to 20 days
Third	10	14.8 ± 4.1	8 to 22 days
First three	10	44.7 ± 4.2	39 to 53 days

Because specimen N delayed about ten days after emerging from the egg before taking an initial bite of grass we have excluded it from the above reckoning.

There are several things about the behavior of the caterpillars that should be recorded. All of the caterpillars stopped feeding for two or three days previous to moulting. Occasionally a caterpillar delayed as much as a day or so after moulting before feeding. Before each moult and before going into hibernation the gut, clearly visible through the caterpillar, was evacuated completely.

Four of the caterpillars exhibited patterns of behavior we suspect are related to genetic influence from *heinemani* that disturbed the "time track". Specimen N, as noted previously did not feed for ten days after emerging from the egg. Since the larvae of *heinemani* usually do not feed after emerging from the egg but go directly into hibernation this action of N may have been an attempt to hibernate that was overcome by either environmental conditions or superior pressure from *inornata* genetic material. Three specimens, C, K, and L, broke off feeding for periods up to twelve days during the third instar. Since Davenport's and Brown's experience with typical *inornata* was that hibernation did not start until some time in the fourth instar, this performance is, or may be, unusual. Specimen C refused to feed from August 17th to the 25th. On that day it resumed feeding but stopped again on the 28th, cleared its gut, and went into hibernation on the 30th. This irregular performance suggests an impulse to hibernate that was not perfect, possibly a single dose of the *heinemani* "time-track" gene. The insect did not

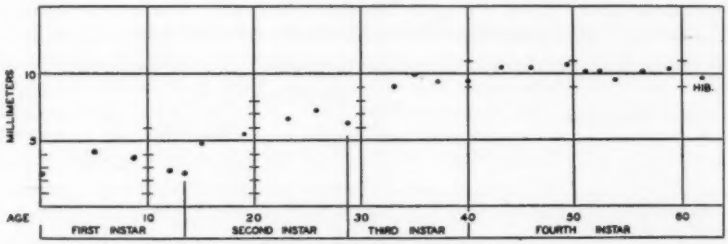


Fig. 2. Growth of a larva of *Coenonympha inornata*.

clear its gut during the long pause in feeding. When it did clear the gut and should have moulted and passed to the fourth instar it instead entered hibernation. Specimen K followed a similar pattern of behavior. This caterpillar did not feed from August 13th through the 25th. It, too, went into hibernation in the third instar on August 31st. Specimen L behaved in a slightly different manner. It stopped feeding on the 17th of August in its third instar. Feeding was resumed in a desultory way on the 26th. This lasted for a few days. Then the gut was evacuated and the third moult passed on the 29th. It fed heavily for a few days and then hibernated in the fourth instar on the 3rd of September.

The growth of the individual caterpillars was rapid during the first few days of each instar. Then longitudinal growth either slowed or ceased and increase in diameter was quite noticeable until the caterpillars were obviously distended and the thoracic diameter markedly greater than the diameter of the head. This is the reverse of the situation immediately after moulting. The data from Specimen A is presented graphically in Fig. 2. Longitudinal shrinkage was noted in every case beginning a few days before moulting.

The Adults of "*inornata*"

In May, 1959, on the 29th Heineman collected a fine series of *Coenonympha* on Grindstone Island. The next day he found four males on Picton Island. These were shipped to Brown to be compared in detail with *heinemani* from the same islands and with *inornata* from Canada. In all respects the spring ("*inornata*") and summer (*heinemani*) broods from Grindstone and Picton Islands resemble each other very closely and differ materially from *inornata* as that taxon appears in Quebec and Ontario. The variables used by Brown (1955) in his study of *inornata* and other eastern North American *Coenonympha* were studied for the island forms and are presented in Tables I and II. The comparative data for *inornata* are taken from the 1955 paper and for *heinemani* from Brown (1958). The information pertaining to "*inornata*" is found in the column labelled "May-June". In all cases a number preceded by plus-minus sign is a standard deviation.

Interpretation of Data and Genetic Hypotheses

Without any geneological material from breeding experiments genetic conclusions are tentative and not proved. However, if certain assumptions are accepted, certain conclusions may be hypothecated. Long experience with members of a genus give the student a feeling or hunch about the variables observed. We believe that the apical ocelli are a genetic characteristic, the expression of which may be controlled by environment, that the absence of the gene for apical ocelli is responsible for absence of the spot on the under side of the fore wing, and that the degree to which the spot is developed on the upper side of the wing is an example of *expressivity* controlled by environment. We believe that the appearance of

TABLE I
Statistics of Variation for certain *Coenonympha* Males

Variable	1000-Islands strains		Ontario & Quebec
	heinemani	"May-June"	*inornata*
Number	34	26	66
Radius of left fore wing, mm.	16.30 ± 0.83	16.29 ± 0.76	17.60 ± 0.62
Coefficient of variation	5.1	4.7	3.5
Color number, mean	8.5	8.5	8.2
Fore Wing			
Ocelli, or traces, on upper side, %	91.2 ± 4.8	61.6 ± 9.5	6.1 ± 2.9
Underside			
Ocelli in Apex, %	100	100	54.6 ± 6.2
Supernumerary ocelli in submargin, %	29.4 ± 7.8	15.4 ± 7.1	0.0
Ray absent, %	2.9 ± 2.2	7.7 ± 5.2	0.0
Ray ends at M_3, %	0.0	15.4 ± 7.1	0.0
Ray ends at Cu_1, %	41.2 ± 8.4	23.1 ± 8.3	13.6 ± 4.2
Ray reaches or exceeds Cu_2, %	55.0 ± 8.5	53.8 ± 9.8	86.4 ± 4.2
Hind Wing, underside			
Ray complete, %	52.9 ± 8.5	46.2 ± 9.8	10.6 ± 3.8
Ray broken, %	41.2 ± 8.4	34.6 ± 9.3	63.6 ± 5.9
Ray ends at M_3, %	5.9 ± 4.7	11.5 ± 6.2	22.8 ± 5.2
Ray fragmentary, %	0.0	7.7 ± 5.2	3.0 ± 2.1
Traces of submarginal ocelli present, %	50.0 ± 8.6	23.1 ± 8.3	0.0
Light basal patches present, %	2.9 ± 2.2	0.0	0.0
Hind Wing, upperside			
Submarginal marks absent, %	100	76.9 ± 8.3	48.5 ± 6.1

TABLE II
Statistics of Variation for certain *Coenonympha* Females

Variable	1000-Islands strains		Ontario & Quebec
	heinemani	"May-June"	*inornata*
Number	11	11	10–11
Radius of left fore wing, mm.	16.79 ± 0.65	16.85 ± 0.71	17.69 ± 0.63
Coefficient of variation	3.9	4.2	3.6
Color number, mean	4.5	4.3	5.0
Fore Wing			
Ocelli, or traces, on upper side, %	100	100	63.7 ± 14.5
Underside			
Ocelli in apex, %	100	100	72.7 ± 13.5
Supernumerary ocelli in submargin, %	63.7 ± 14.5	45.5 ± 15.0	0.0
Ray absent, %	0.0	9.1 ± 8.6	0.0
Ray ends at M_3, %	9.1 ± 8.6	0.0	0.0
Ray ends at Cu_1, %	36.4 ± 14.5	36.4 ± 14.5	20.0 ± 12.5
Ray reaches or exceeds Cu_2, %	54.5 ± 15.0	54.5 ± 15.0	80.0 ± 12.5
Hind Wing, underside			
Ray complete, %	63.7 ± 14.5	54.5 ± 15.0	60.0 ± 15.0
Ray broken, %	27.3 ± 13.5	36.3 ± 14.5	40.0 ± 15.0
Ray ends at M_3, %	9.1 ± 8.6	0.0	0.0
Ray fragmentary, %	0.0	9.1 ± 8.6	0.0
Traces of submarginal ocelli present, %	63.7 ± 14.5	45.5 ± 15.0	0.0
Light basal patches present, %	0.0	0.0	0.0
Hind Wing, upper side			
Submarginal marks absent, %	100	100	20.0 ± 12.5

supernumerary ocelli on the under side of the fore wing (and sometimes also expressed on the upper side) is controlled by a different gene or genes. We believe that the appearance of the submarginal ocelli on the under side of the hind wing is controlled by still another gene, and that the degree to which they are developed may be an example of *penetrance*. We believe that the rays on the under sides of the wings may be controlled by a single gene and the degree to which they are developed may be an example of *penetrance*. We believe that color is largely environmental and is controlled by humidity (see Brown, 1955, p. 396-397). With these assumptions we will proceed to analyse the data we have. In no case do we feel that we have seen or measured adequate samples. This is especially true for the female series.

Size

The size of the males, as measured by the radius of the left fore wing, is for all purposes the same for the two groups of specimens from the Islands. The standard deviation of the difference between the pooled male sample from the Islands and the male sample from Quebec and Ontario is 0.74 mm. The difference between the means for the two samples is 1.30 mm. Using Fisher's method (1950, p. 122), t is found to be 7.4. "Student's" table for t tells us that there is considerably less than one chance in a hundred that the two samples, that from the Islands and that from the mainland, were drawn from the same population. The males of the Thousand Islands strains are statistically smaller in size than those of *inornata*. Similar treatment of the data for females supports this conclusion. Since size may be influenced by nutrition and the two Island samples were collected in the same wet meadows, the variation in size may have no taxonomic meaning.

Color

Our measure of color is so subjective that the slight differences observed among the males and again among the females may have no meaning. The males definitely are darker than the females in each of the samples studied.

Apical Ocelli on the Fore Wing

All of the males collected on the Thousand Islands, both in the spring time and during late summer, bear ocelli on the under side of the fore wings. Only a few more than half of the Ontario and Quebec *inornata* males are so marked. Using the Four-ply Table method for computing Chi-square as a test of independence we found Chi-square to be 0.90. From Pearl's table of chi-square (1940, p. 480 *et seq.*) for one degree of freedom we find that there is 0.34 chance that the appearance of ocelli in the apex of the fore wing is independent of the strain being examined. We interpret this to mean that we are safe in saying only that *inornata* tends to be less ocellate in this respect than either strain from the Thousand Islands. A similar situation prevails among the females.

If we assume that the presence of an ocellus is occasioned by a dominant gene, then, using the Hardy-Weinberg principle, the gene-pool of *inornata* from Ontario and Quebec is about 35% dominant for this character. Since none of the males from the Thousand Islands lacked the ocelli, it means either lack of the recessive form of the gene in these strains or so low a frequency among either of the two samples that the homozygous recessive condition was not captured once among the 60 males examined. It is probable that the gene-pool of both spring and late-summer *Coenonympha* on Grindstone and Picton Islands are at least 80% saturated with the dominant gene for this ocellus.

Supernumerary Ocelli

One of the diagnostic characteristics for *heinemani* used by Brown was the occurrence of ocelli on the under side of the forewing in addition to the usual apical one. These are either absent or very rare among Ontario and Quebec *inornata* since none of the 66 males examined bear the slightest indication of such marks. If the gene that controls these is present in the gene-pool of *inornata* its frequency probably is less than 0.8%.

Both the spring and summer broods on the Thousand Islands show these ocelli on both sexes. Using a Four-ply Table and Chi-square test, there is only one chance among 40 that there is no significance to the greater frequency of these ocelli on the female than on the male.

Using the usual method it appears that the male gene-pool of *heinemani* is about 16% dominant for these ocelli and the female gene-pool 40% dominant. Similar computations show that "*inornata*", the spring brood, male gene-pool is only 8% dominant and the female gene-pool 26% dominant for these marks.

Submarginal Ocelli on the Hind Wing

On no specimen from eastern North America that we have examined are these ocelli as well developed as they are on western representatives of *tullia* such as *ochracea, furcae* and *subfusca.* Apparently the eastern strains contain a "suppressor" gene, or lack an "intensifier", or the ocelli are polygenic and there is a reduced number of genes in the eastern strains. On very few specimens of eastern taxa have we seen more than two ocelli, often only one on each wing. The most persistent ocellus is the one that lies between veins M_3 and Cu_1. No specimen of *inornata* from Ontario and Quebec has been seen by us with these ocelli. On the Thousand Islands strains the ocelli usually are indicated just by a cluster of whitish scales, sometimes this has a tiny black pupil.

Four-ply Tables for the occurrence of these ocelli on the two sexes of *heinemani* yield a Chi-square of 0.621. The probability that there is a sex difference is low, about 0.6. The smaller sample of spring brood "*inornata*" produced a higher probability, 0.83. However in neither case is the probability high enough to warrant a categorical statement that the appearance of the ocelli is strongly influenced by the sex of the specimen.

The frequency with which the gene for ocelli appears in the gene-pool of male *heinemani* probably is about 29%, for the female gene-pool about 40%. If there is no sex influence the total *heinemani* gene-pool is 32% saturated for this ocellus character. The frequency for the May-June insects probably are: for males, 12%; for females, 26%; for the total pool, 16%.

The Ray on the Under Side of the Fore Wing

The tendency is for both of the Thousand-Island strains of *tullia* to have this mark less than fully developed more often than that condition occurs among *inornata* from Ontario and Quebec. The sex of the specimen seems to have no relationship with the development of the ray.

The Ray on the Under Side of the Hind Wing

The reverse of conditions found on the fore wing occur on the hind wing. The tendency is for the Thousand Island strains to have this line fully developed more frequently than occurs among *inornata* from Ontario and Quebec.

If we assume that the normal condition is to have the rays on both fore and hind wings fully developed, an assumption that seems reasonable in light of their appearance on the majority of forms of *tullia*, nearctic and palearctic, then we may

account for fragmentation and reduction of the rays by a gene or condition that prevents complete penetration. Applying this thesis we find the following probable:

Strain	The Ray on the Fore Wing. Concentration of "Suppressor".		Combined sexes
	males	females	
inornata	7%	11%	8%
"*inornata*"	27%	26%	26%
heinemani	25%	33%	28%

Strain	The Ray on the Hind Wing. Concentration of "Suppressor".		Combined sexes
	males	females	
inornata	67%	23%	58%
"*inornata*"	32%	26%	32%
heinemani	27%	20%	25%

In both of these cases the gene-pools of "*inornata*", the spring insect on the Thousand Islands, are not significantly different from *heinemani* gene-pools. In both cases the gene-pools of the Island strains are different from the pools of the mainland strain called *inornata*. In both cases the tendency is for "*inornata*" to vary from *heinemani* in the direction of the mainland taxon.

Summary and Taxonomic Conclusion

We are faced with a curious situation. There are two broods of *Coenonympha tullia*, in its broadest sense, found in the same wet meadows on Picton and Grindstone Islands among the Thousand Islands in the St. Lawrence River, off Clayton, New York. (Fig. 3). We presume that these insects will be found on other islands in the group, in fact, a colony has been located, but not sampled, on adjacent Wellesley Island.

What evidence we have from the Islands, based upon life-histories, suggests very strongly that the May-June brood does not give rise to the late summer brood, but to the next spring brood. The late summer brood likewise represents a single-brooded butterfly, giving rise to the next year's late summer brood. Brown (1955, p. 402) found only very rare evidence for a partial second brood among *inornata* from eastern Canada, a single specimen from Thompsonville, Simcoe Co., Ontario, captured on 21 August.

We believe that in the past there were to be found on the islands in question two well defined taxa, typical *inornata* flying in May and June and typical *heinemani* flying in late August and September. The rare occasion upon which these two taxa were hybridized on the islands through unusually early emergence of a *heinemani* male, or unusually late appearance for an *inornata* female, or the rare appearance of a second brood individual of *inornata*, we believe has lead to the infiltration of the spring material with genes from the *heinemani* pool that have impressed upon the spring brood many of the characteristics in appearance of the late summer form of *tullia*.

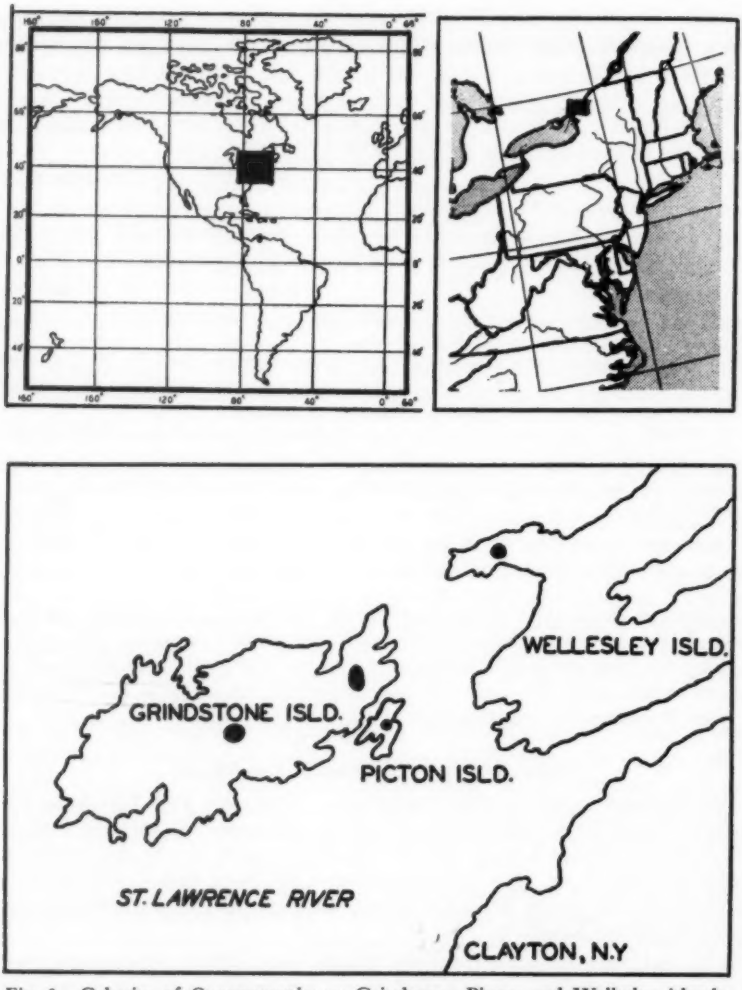


Fig. 3. Colonies of *Coenonympha* on Grindstone, Picton and Wellesley islands.

There is a slight difference in the proportions of the eggs of the two broods. Since we have no information about the sizes of eggs from successive broods among the strains that are doublebrooded, such as are found on the West Coast of the United States, we cannot say that this has any importance. Other than size, there apparently are no significant observable differences between the larvae of the two broods in the first and second instars. On the basis of life histories the two broods seem to be independent taxa.

A close examination of certain variable items in the pattern of the imagos strongly indicates that there is very little difference in the appearance of the two broods, "*inornata*" in the spring and *heinemani* in late summer. Analysis of hypothetical gene-pools of the two suggest that the spring specimens' pool approaches that of the summer brood but varies from it in the direction of *inornata*. The pertinent data may be summarized in tabular form:

Variable	Hypothetical concentration		
	heinemani	"*inornata*"	*inornata*
Apical ocellus	100% (?)	80% (?)	33%
Supernumerary ocelli			
Males	15%	8%	0% (?)
Females	40%	26%	0% (?)
Submarginal ocelli	100% (?)	80% (?)	0% (?)
Fore wing ray "suppressor"	28%	26%	8%
Hind Wing ray "suppressor"	25%	32%	58%

Thus the "*inornata*" gene-pool is so like that of *heinemani* for the items analyzed that we may well consider the May-June butterflies to be *heinemani*, slightly contaminated by *inornata*.

If the early hibernation of *heinemani* in the first instar, rarely in the second, is caused by a double dose of a gene, and the late hibernation of *inornata* in the fourth instar is brought about by absence of that gene, then a single dose in *heinemani* brought about by hybridization with *inornata* may cause the caterpillars to avoid hibernation until it is too late and they are killed by cold, thus preserving the *heinemani* gene-pool in a relatively pure state. On the other hand, the hesitation noted in the cases of four spring-brood caterpillars, one upon emergence from the egg, the others during the third instar, may indicate the effect of a double dose and a single dose of the "hibernation-gene" from *heinemani* in an insect that is physiologically closely allied to *inornata*. If this is so the concentration of the gene in the spring brood is about 10%.

All of this leaves us in a taxonomic quandary. What shall be done about the spring brood strain of *Coenonympha tullia* on the Thousand Islands? We have here a self-maintaining brood that is in appearance, for all practical purposes, identical with another independent taxon, *heinemani*. The imitator-brood, however, seems to have the physiology of another independent taxon, *inornata*. Our solution is to consider the spring brood to be *inornata* that has been contaminated with some genes from the *heinemani* gene-pool. That the contaminating genes are essentially those involved with superficial appearances and not fundamental physiology. We believe that no new name should be proposed for this hybrid brood, that it should be recognized as just that.

References

Brown, F. Martin. 1955. Studies of Nearctic *Coenonympha tullia* (Rhopalocera, Satyridae). *Coenonympha tullia inornata* Edwards. *Bull. Amer. Mus. Nat. Hist.* 105: 359-410, 19 figs., 2 pls., 21 tables.

Brown, F. Martin. 1958. A New Subspecies of *Coenonympha nipisiquit* McDunnough from New York State. *J. New York Ent. Soc.* 64: 63-73, 1 pl.

Davenport, Demorest. 1941. The butterflies of the Satyrid genus *Coenonympha*. *Bull. Mus. Comp. Zool., Harvard College* 87: 215-349, 10 pl.

(Received February 12, 1960)

Weather and Outbreaks of the Spruce Budworm in the Province of Quebec from 1939 to 1956[1]

By J. G. Pilon and J. R. Blais[2]

Introduction

Nearly all forest regions in the Province of Quebec where balsam fir (*Abies balsamea* (L.) Mill.) is an important tree component have been subjected to severe defoliation by the spruce budworm, *Choristoneura fumiferana* (Clem.), during the past 20 years. These outbreaks have followed an easterly direction beginning near the Ontario-Quebec border in 1939 and ending in the Gaspé Peninsula in 1958.

It has been shown by Wellington *et al.* (1950) that the beginning of a number of outbreaks in northeastern North America were preceded by a period of three or four years of early summer drought. Greenbank (1956) was able to show a similar relationship in recent spruce budworm outbreaks in New Brunswick. The present studies were undertaken to test the theory of climatic release with respect to outbreaks that have occurred in Quebec between 1939 and 1958.

The Annual Reports of the Forest Insect Survey, Province of Quebec, have presented spruce budworm outbreak data on the basis of 21 economic regions; these regions were retained for the present studies (Fig. 1). A somewhat broad correlation exists between these economic regions and recognized climatic and ecological zones of Quebec. In the past 20 years, spruce budworm outbreaks occurred in 14 of the regions listed and described briefly in Table I. The boreal forest is the predominant type throughout most of the territory, but there is a greater preponderance of hardwoods where extensive intrusions of the Great Lakes-St. Lawrence forest occur in the Ottawa, North of Montreal, South Shore, Lower St. Lawrence, and Matapedia regions (Halliday, 1937).

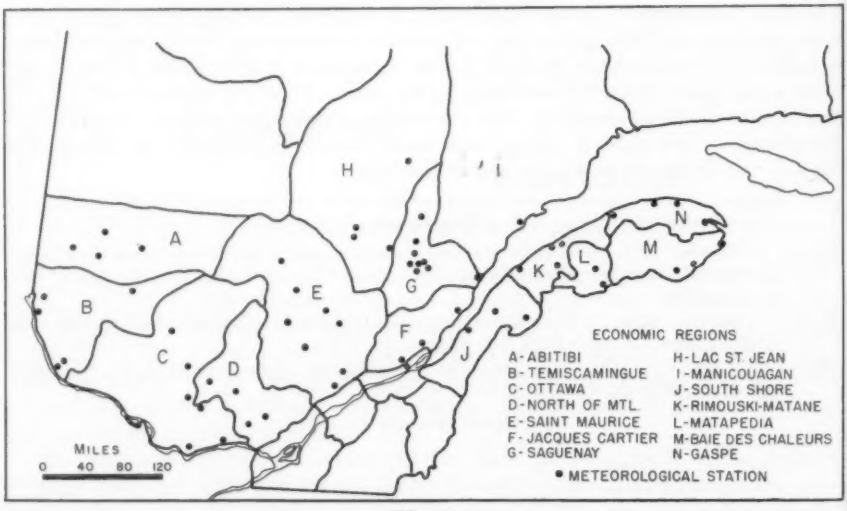


Fig. 1

[1]Contribution No. 658, Forest Biology Division, Research Branch, Department of Agriculture, Ottawa, Canada.

[2]Forest Biology Laboratory, Quebec, P.Q.

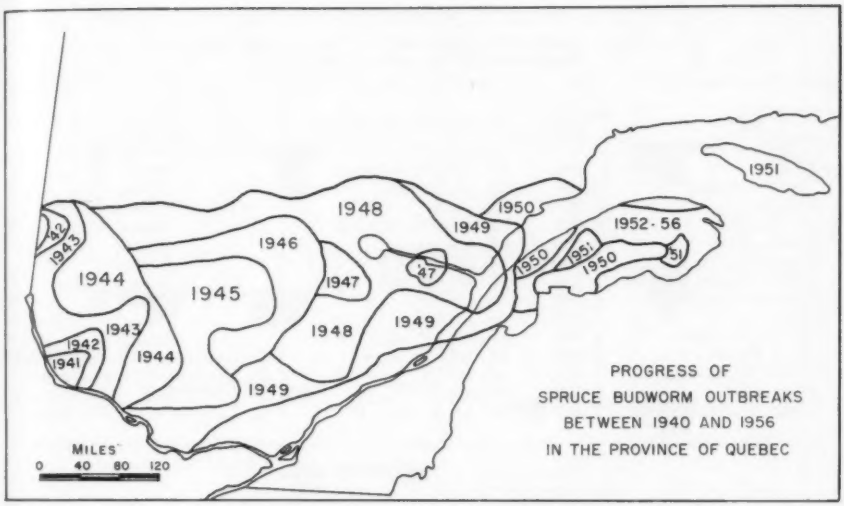


Fig. 2

Progress of Spruce Budworm Outbreaks

According to the Forest Insect Survey reports the spruce budworm outbreaks developed in four more or less distinct phases (Fig. 2). The insect first reached outbreak proportions in 1939 around Duparquet and Hébécourt near the Ontario boundary, and in the next three years spread through the western parts of the Abitibi, Temiscamingue, and Ottawa regions. The second phase took place between 1943 and 1945 when the outbreak spread to the eastern portions of these regions and new outbreaks appeared in the North of Montreal Region and western sectors of the St. Maurice Region. During the third phase, which took place between 1946 and 1949, insect numbers reached outbreak proportions in the eastern St. Maurice, Lac St. Jean, Saguenay, Jacques Cartier, Manicouagan, South Shore, and Lower St. Lawrence regions. Finally, in the fourth phase, outbreaks appeared in the Matapedia and Baie des Chaleurs regions in 1950 and in the Gaspé Region in 1951. By this time the insect was also unusually abundant on Anticosti Island.

The progress of the outbreaks in an easterly direction is unmistakable. This trend has also been observed in other regions (Wellington *et al.*, 1950; Greenbank, 1956).

Prevailing June Precipitation

Weather data for the regions under study were obtained from the *Monthly Record*, Canada, and from the *Meteorological Bulletin*, Quebec, for the years 1931 to 1956. For each economic region studied, meteorological stations were selected on the basis of geographical position and the number of years for which data were available. The location of the selected stations is shown in Figure 1. An effort was made to obtain weather data from all sectors; unfortunately, there were fairly extensive areas for which no data are available.

Since the greater part of the active larval stage of the spruce budworm is passed in June, weather conditions during this month can be considered as being particularly critical. Precipitation for the month of June for each year was

TABLE I

Area in square miles, important tree species and forest classification of the regions under study

Region	Area in sq. miles	Important tree species	Forest classification*
Abitibi	13,000	bF. wS. bS. wB. tL.	Boreal
Temiscamingue	10,300	bF. bS. jP. wB.	Boreal
Ottawa	18,000	bF. bS. jP.	Boreal
St. Maurice	18,800	bF. wS. bS. wB. yB.	Boreal
Lac St. Jean	20,000	bF. bS. wB.	Boreal
Saguenay	6,000	bF. bS. yB. c.	Boreal
Manicouagan	21,000	bF. bS. jP. wB.	Boreal
Baie des Chaleurs	4,700	bF. wS. bS.	Boreal
Gaspe	3,400	bF. wS. bS.	Boreal
Jacques-Cartier	4,300	bF. bS. jP. wB.	Boreal
South Shore	5,000	bF. wS. bS. tL. c.	St. Lawrence & Boreal Forest
Lower St. Lawrence	3,100	bF. wS. tL. c.	St. Lawrence & Boreal Forest
Matapedia	2,400	bF. wS. bS. tL. c.	St. Lawrence & Boreal Forest
North of Montreal	7,400	bF. bS. h. wP. yB. sM.	St. Lawrence & Boreal Forest

bF: Balsam Fir
wS: White Spruce
bS: Black Spruce
jP: Jack Pine
wP: White Pine
wP: White Birch
yB: Yellow Birch
C: Cedar
tL: Tamarack
h: Hemlock
sM: Sugar Maple

* According to Halliday's classification.

compared with the June mean for the period 1931-56 to determine the deviations from normal. The regional June rainfall for each year was obtained by averaging the total June rainfall for all the selected stations within the region. The normal June rainfall for each region was calculated by dividing the total regional June rainfall by 26, the number of years being investigated. Since Wellington *et al.* (1950) found that outbreaks developed following the accumulated effect of four years of early summer drought, the deviation from normal for each four-year running average was calculated for each region. This was obtained by dividing by four the total deviation for each successive four-year period between 1931 and 1956; the deviations were expressed in percentages and converted to histograms (Fig. 3). This figure indicates that there were three general periods of dry Junes in the Province of Quebec during the 26 years under investigation. The first was from about 1934 to 1940, and was more severe in the western part of the Province. A second and more pronounced dry period started in the west about 1945 and ended in the east about 1951. This drought was general throughout the Province during the four-year periods ending in 1946, '47, '48 and '49, and was especially pronounced for the four-year periods ending in 1947 and 1948. A third period started about 1954 and gained in amplitude until 1956, the last year being considered in these studies.

Precipitation and the Initiation of Outbreaks

When the timing of spruce budworm outbreaks was related to the precipitation pattern, 12 of the 14 regions under study had been subjected to dry Junes for four years or more immediately preceding the outbreaks (Fig. 3). In the North of Montreal and St. Maurice regions the relationship did not hold. Three-year running averages of June rainfall were calculated for these two regions, and precipitation data for June and the first two weeks in July were considered, but in all cases, precipitation in the years preceding the outbreaks was above normal.

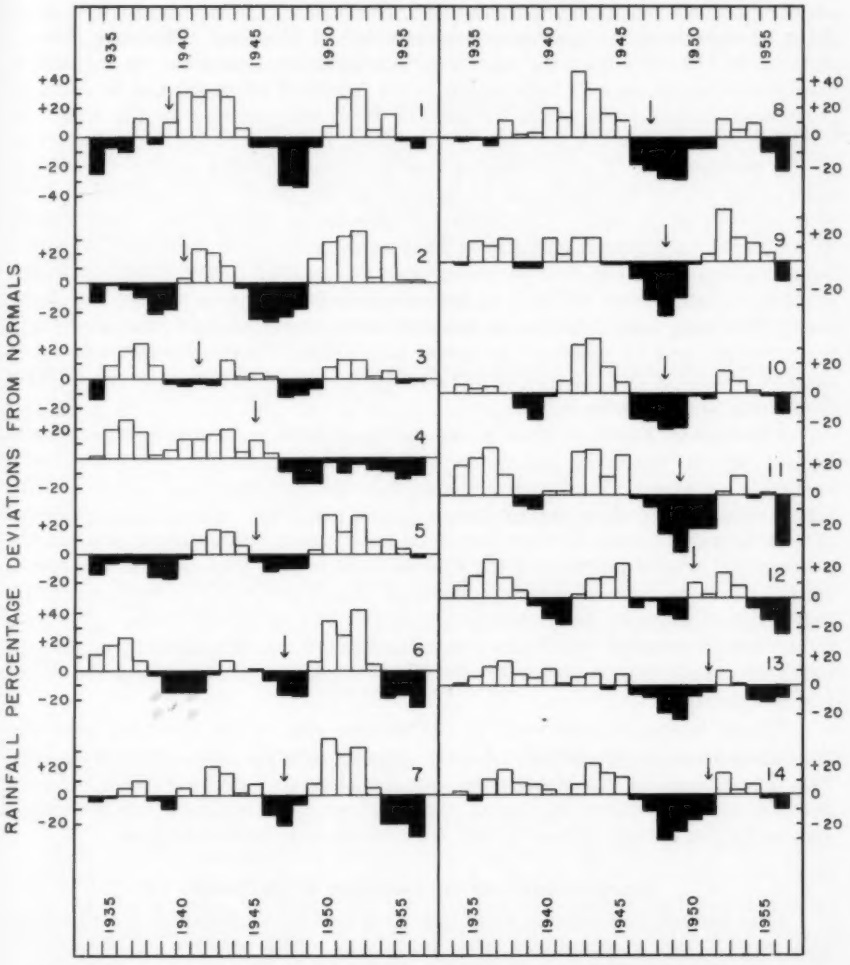


Fig. 3. Four-year running averages of percentage deviations from normal June rainfall plotted over the fourth year for each of the 14 regions studied for the 1934-56 period. 1. Abitibi, 2. Temiscamingue, 3. Ottawa, 4. North of Montreal, 5. St. Maurice, 6. Lac St. Jean, 7. Saguenay, 8. Jacques Cartier, 9. Manicouagan, 10. South Shore, 11. Lower St. Lawrence, 12. Matapedia, 13. Baie des Chaleurs, 14. North Gaspe. Arrow indicates first year of outbreak in each region.

Notwithstanding these two exceptions the association between a prolonged decline in precipitation in early summer and the initiation or spread of spruce budworm outbreaks is very striking.

The appearance of outbreak conditions in the North of Montreal and the St. Maurice regions despite unfavourable weather conditions bears further examination. Although outbreaks were not recorded in these regions until 1945, surveys had indicated the existence as early as 1942 of areas of light attack varying in size from a few to one or two hundred square miles (Daviault, 1951). It is well known that spruce budworm adults can be transported for long distances by

convectional air currents (Henson, 1951; Greenbank, 1957). In 1944, a moth flight of considerable importance was recorded in Montreal (Daviault, 1949) a distance of 130 miles from the nearest spruce budworm outbreak. It is possible, therefore, that the areas of light attack in the North of Montreal and St. Maurice regions originated from adults transported from the outbreak to the west. In 1944 and 1945, June was a dry month throughout the western and central portions of the Province and it is conceivable that this short drought period might have sufficed to permit the outbreak to develop in the North of Montreal and St. Maurice regions in 1945. The increase in population through the transportation of moths by air currents could have been equivalent to the increase that would have resulted from the two or three years of summer drought that generally precede a change from endemic to epidemic conditions. One or two dry Junes might then have been sufficient to consolidate the scattered light infestations into a continuous area of moderate to severe infestation. Moth dispersal was also a marked feature of the progress of the current spruce budworm outbreak in New Brunswick (Greenbank, 1957).

The data in Figure 3 show prolonged periods of early summer drought in certain regions, especially during the 1934-40 phase, when no spruce budworm outbreaks occurred. It is generally accepted that outbreaks only occur in areas where extensive stands of mature balsam fir are prevalent. Since great quantities of merchantable balsam fir were destroyed by a spruce budworm outbreak in the western and central portions of the Province about 1910 (Swaine and Craighead, 1924), a certain lapse of time was required before the forest could again attain that stage of maturity associated with susceptibility to spruce budworm attack. Even though weather conditions were suitable for the development of an outbreak in certain regions prior to the 1940's, none occurred because the forest was too young.

Spruce budworm outbreaks in the eastern part of the Province generally developed after longer periods of early summer drought than in the west (Fig. 3). The reason for this is not clear, but the history of past outbreaks indicates that the more maritime regions of the Province have sustained less prolonged attacks by the spruce budworm than the central and western regions.

Temperature and the Initiation of Outbreaks

June temperature records were treated in the same manner as the precipitation records, but no consistent relationship was found between air-temperature changes and spruce budworm population changes. In the 14 regions being considered, spruce budworm outbreaks began after a four-year period of temperatures above normal in six regions, of temperatures below normal in seven regions, and of normal temperatures in one region. Wellington *et al.* (1950) also found no relationship between the initiation of spruce budworm outbreaks and air temperature.

Conclusions

The progress of spruce budworm outbreaks across the Province of Quebec between 1939 and 1951 supports the theory of climatic release. Successive early summer drought periods undoubtedly occasioned endemic populations to react and resulted in the progressive appearance of outbreaks in regions from west to east. Moth dispersal in the direction of the prevailing winds must also have been a contributing factor and helps to explain the progress of outbreaks in the two regions where prolonged drought periods did not occur.

These two factors, climatic release and dispersal of adults apparently acted concurrently and their united action was responsible for the rapid progress of spruce budworm outbreaks across Quebec.

Acknowledgments

Grateful appreciation is expressed to Dr. L. Daviault, Officer-in-Charge of the Forest Biology Laboratory, Quebec, for suggesting this study. The authors wish to thank the following members of the Forest Biology Division who kindly reviewed the manuscript: Dr. B. M. McGugan, Associate Director, Dr. W. G. Wellington, Head, Bioclimatology Section, and Dr. C. F. MacLeod, Research Officer, Quebec Laboratory.

References

Daviault, L. 1949. Notes pour servir à l'histoire de la tordeuse des bourgeons de l'épinette. *Forêt et Conservation* 1: 329-331.

Daviault, L. 1951. Supplément au rapport annuel, Bureau d'Entomologie, Ministère des Terres et Forêts. Unpublished report.

Greenbank, D. O. 1956. The role of climate and dispersal in the initiation of outbreaks of the spruce budworm in New Brunswick. I. The role of climate. *Can. J. Zool.* 34: 453-476.

Greenbank, D. O. 1957. The role of climate in the initiation of outbreaks of the spruce budworm in New Brunswick. II. The role of dispersal. *Can. J. Zool.* 35: 385-403.

Halliday, W. E. D. 1937. A forest classification for Canada. *Can. Dept. Mines and Res., For. Serv. Bull.* 89: 1-50.

Henson, W. R. 1951. Mass flights of the spruce budworm. *Canad. Ent.* 83: 240.

Swaine, J. M., and F. C. Craighead. 1924. Studies on the spruce budworm *Cacoecia fumiferana* Clem. *Can. Dept. Agr., Tech. Bull.* 37 (n.s.).

Wellington, W. G., J. J. Fettes, K. B. Turner, and R. M. Belyea. 1950. Physical and biological indicators of the development of outbreaks of the spruce budworm *Choristoneura fumiferana* (Clem.) (Lepidoptera: Tortricidae). *Can. J. Research, D.* 28: 308-331.

(Received June 9, 1960)

Three New Species of *Contarinia* Rond. (Diptera: Cecidomyiidae) in Douglas-Fir Needles[1]

By S. F. CONDRASHOFF[2]

Felt (1940) mentioned a midge in Douglas-fir needles which he called *Cecidomyia* sp.; this reference was quoted by Barnes (1951). Denton (1954) reported that a midge, identified by the Division of Insect Identification, United States Bureau of Entomology and Plant Quarantine as *Cecidomyia* sp., occurred in needles of Douglas fir in northeastern Washington, northern Idaho, and northeastern Montana. In 1954 the author reared some adults which H. F. Barnes (in litt. 1957) referred to the genus *Contarinia* Rond. Unpublished records from 1935 to date indicate unidentified needle-inhabiting gall midges throughout most of the host range. Recently the author found indications of a species complex which were confirmed by further rearings of adults. This paper presents the description of three new species of *Contarinia* Rond., reared under similar conditions, from material obtained at Oyama, B.C.

Key to Species of *Contarinia* from Douglas-Fir Needles

MALES

1. Lobes of dorsal plate rounded 2
   Lobes of dorsal plate truncate ..... *Contarinia pseudotsugae* n. sp.
2. Dorsal plate with shallow, basally rounded cleft; style slender ..... *C. constricta* n. sp.
   Dorsal plate with deep V-shaped cleft; style stout ..... *C. cuniculator* n. sp.

[1]Contribution No. 648, Forest Biology Division, Research Branch, Department of Agriculture, Ottawa, Canada; based on a thesis for presentation to the Faculty of Graduate Studies at the University of British Columbia, in partial fulfilment of the requirements for the degree of Master of Arts.

[2]Forest Biology Laboratory, Vernon, B.C.

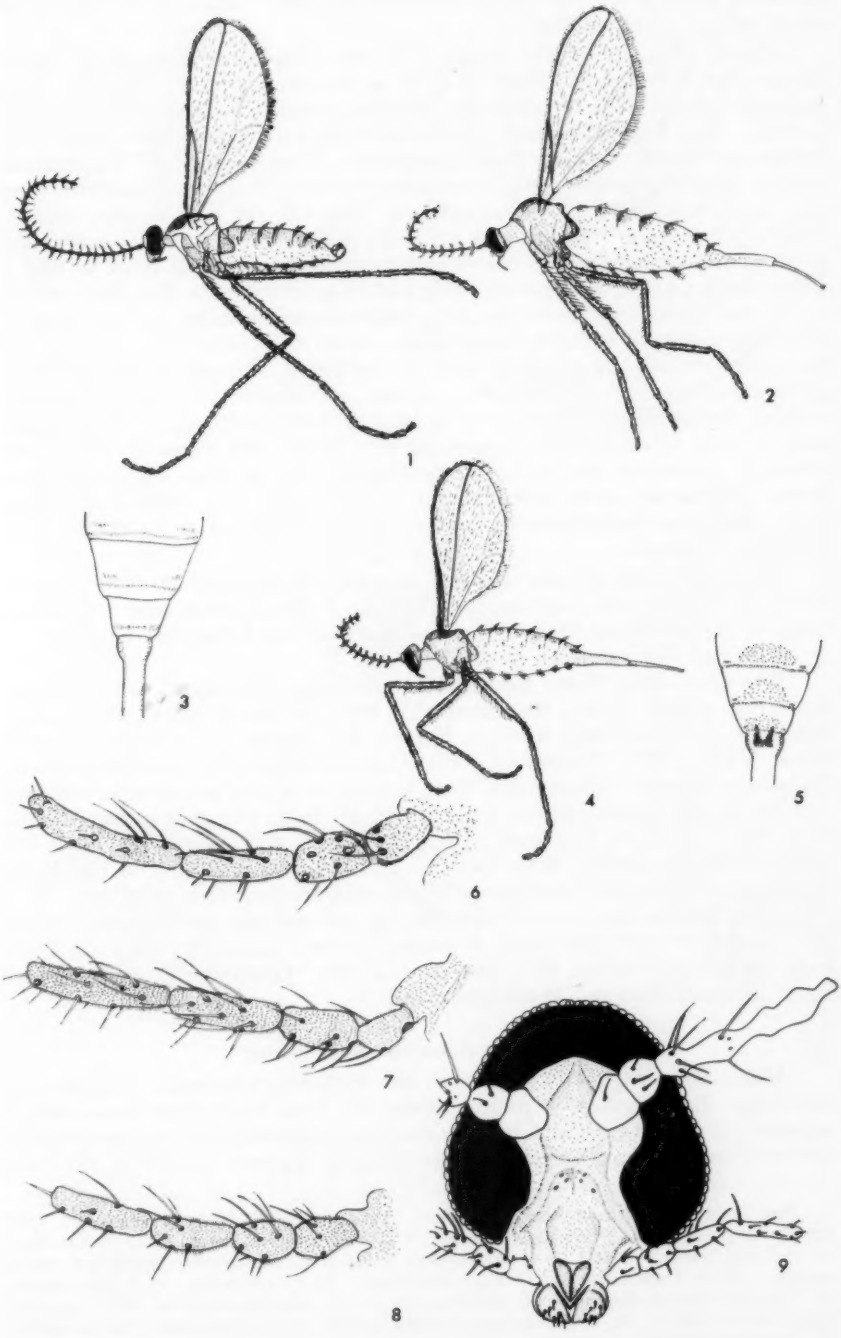
FEMALES

1. Ovipositor without pigmented patch at base, tip cylindrical 2
   Ovipositor with pigmented patch at base, tip heart-shaped ..... *C. cuniculator* n. sp.
2. Apical palpal segment irregular, 1¾ times longer than third segment ..... *C. pseudotsugae* n. sp.
   Apical palpal segment cylindrical, 1½ times longer than third segment ..... *C. constricta* n. sp.

Contarinia pseudotsugae new species

Male (Fig. 1):—Body length 1.74 (1.51-2.05) mm., excluding terminalia. Head about as deep as broad; eyes holoptic, black. Antenna 1.34 mm. long, tapering gradually, with 12 bi-nodose flagellar segments in addition to scape and pedicel. First two flagellar segments fused; distal stem of second flagellar segment about 1½ times longer than distal stem of first flagellar segment. Proximal node of each flagellar segment slightly broader than distal node; proximal node and stem four-fifths as long as distal node and stem; each node about as long as corresponding stem. Diameter of each stem of fifth flagellar segment (Fig. 11) about one-third the diameter of the corresponding node. The circumfila radiate from bases situated just above the widest portion of each node and extend, when in a vertical position, to the middle of each succeeding node; stout bristles on the lower half of each node somewhat longer than circumfila. Total length of 11th flagellar segment, diameter of nodes, and diameter of stems is nine-tenths, four-fifths, and one-half respectively, of that of the first flagellar segment. Palpus (Fig. 6) quadriarticulate, covered with fine pili, and bearing stout setae; basal segment short, nearly globular; second segment cylindrical, slightly longer and broader than the first; third segment distinctly narrower and 1½ times longer than second; apical segment of same breadth as the third but almost 1¾ times longer and irregularly shaped. Thorax yellowish-brown, 0.63 mm. long. Wing hyaline, 1.85 mm. long, 0.72 mm. broad; veins very lightly pigmented; second vein well out from costa, joining costa fairly abruptly; third vein interrupting costa just behind apex of wing; fifth vein forked. Length of legs and proportions of their parts as follows: prothoracic 2.49 mm.—femur 0.27, tibia 0.27, first + second tarsal segment 0.24, third 0.11, fourth 0.07, apical 0.04; mesothoracic 2.34 mm.—femur 0.28, tibia 0.28, first + second tarsal segment 0.23, third 0.10, fourth 0.07, apical 0.04; metathoracic 2.75 mm.—femur 0.30, tibia 0.26, first + second tarsal segment 0.23, third 0.10, fourth 0.07, apical 0.04. Posterior edge of each femur with long, backward projecting setae. Claws (Figs. 12, 13) simple, curved, about half the length of the empodium. Empodium broad at apex, gently tapering to base of claws; upper surface covered with fine pili. Pulvilli slender, less than half length of claws. Abdomen 1.02 mm. long (excluding terminalia), pale orange, with a dark narrow transverse band at posterior margin of each segment, these bands bearing long setae and extending across the dorsum to the lateral line; just anterior to the base of these bands are short, narrow, vertical dark patches also bearing long setae. The venter also bears setae. Terminalia (Figs. 16, 17) with basistyle stout, twice as long as broad, with long stout setae; dististyle stout, moderately curved, finely crenulate, with sparse fine setae and a broad serrated terminal claw (Fig. 20). Dorsal plate broad, triangular in shape, moderately clothed with pili, bilobed, abruptly emarginate with a moderately deep, basally rounded, cleft; lobes truncate, with several prominent setae at the apex. Ventral plate bilobed, half as long as basistyle; each lobe twice as long as broad, densely clothed with dark pili, cleft

Figs. 1-9. 1. *Contarinia pseudotsugae* (male). 2. *C. pseudotsugae* (female). 3. Dorsal aspect of tip of abdomen and base of ovipositor of *C. pseudotsugae*. 4. *C. cuniculator* (female). 5. Dorsal aspect of tip of abdomen and base of ovipositor of *C. cuniculator*. 6-8 Palpi. 6. *C. pseudotsugae*. 7. *C. constricta*. 8. *C. cuniculator*. 9. Head (frontal aspect) of *C. pseudotsugae* (female).


1
2
3
4
5
6
7
8
9

extending about as far cephalad as cleft of dorsal plate. Style moderately broad, about as long as ventral plate.

Female (Fig. 2):—Body length 1.79 mm. (excluding ovipositor), colour darker than in the male. Head (Fig. 9) as in male. Antenna 1.09 mm. long, tapering slightly, with 12 cylindrical flagellar segments in addition to scape and pedicel. Each flagellar segment consists of a basal enlargement and a stem. First and second flagellar segments fused, enlargement of each elongated. Enlargement of each flagellar segment gently constricted toward the base with the narrowest part at the basal third of the enlargement. Stem of the fifth flagellar segment (Fig. 10) half to one-third as long and slightly less than half as broad as corresponding enlargement, both the stem and enlargement are about twice as long as broad; basal setae of enlargement long and stout, distal setae finer and tending to be more concentrated on one side; enlargement encircled by two rings of appressed circumfila joined by longitudinal trunks at opposite sides. Thorax 0.60 mm. long. Wings 1.93 mm. long and 0.73 mm. broad. Length of legs as follows: prothoracic, 1.94 mm.; mesothoracic, 1.88 mm.; metathoracic, 2.46 mm. Abdomen without distinctive markings, 1.17 mm. long, excluding ovipositor. Ovipositor as long as body when extended; appearing soft, fleshy, and wrinkled with a subspherical expansion at base and cylindrical bilobed tip; tip (Figs. 21, 23) 1⅓ times longer than broad, about half diameter of shaft, somewhat tapered with long, fairly stout setae; no pigmented patch on dorsum of base (Fig. 3). Other characteristics as in male.

Holotype:—Male, Oyama, British Columbia, Canada, April 25, 1959 (Condrashoff), reared from larva from needle of Douglas fir, *Pseudotsuga menziesii* (Mirb.) Franco. Type number 7114, in the Canadian National Collection, Ottawa.

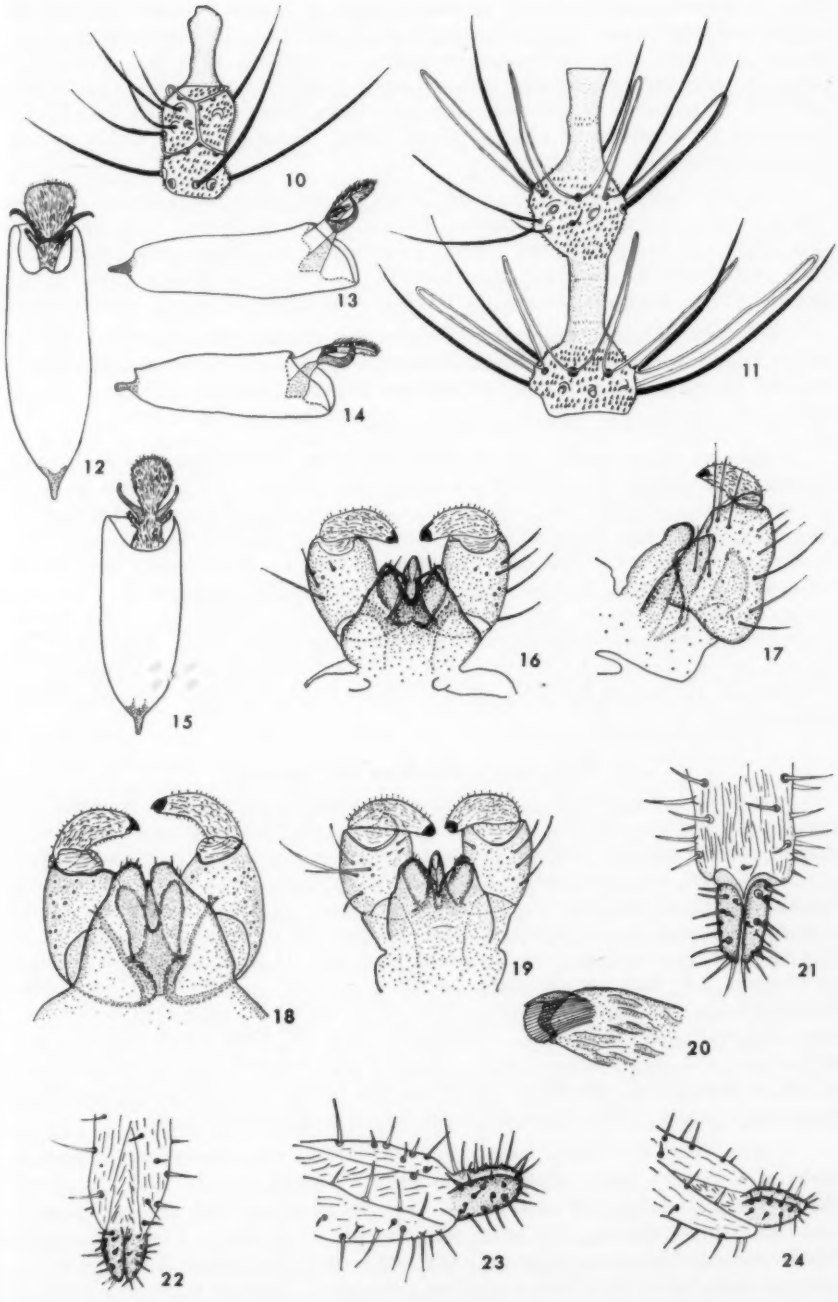
Allotype:—Female, same data as holotype.

Paratypes:—Four males, four females, same data as holotype; three male and two female pupae, Oyama, B.C., March 23, 1959; two female pupae, Oyama, B.C. March 25, 1959; five instar II larvae, Vernon, B.C. August 22, 1959; five instar III larvae, Vernon, B.C., October 13, 1959 (Condrashoff), in the Canadian National Collection, Ottawa. Three males, three females, same data as holotype; one male and two female pupae, Oyama, B.C., March 23, 1959; two male pupae, Oyama, B.C., March 25, 1959; five instar II larvae, Vernon, B.C., August 22, 1959; five instar III larvae, Vernon, B.C., October 13, 1959 (Condrashoff), in the Barnes Collection, Rothamsted Experimental Station, Harpenden, Herts., England. Two males, two females, same data as holotype; two male and one female pupae, Oyama, B.C., March 23, 1959; five instar II larvae, Vernon, B.C., August 22, 1959; five instar III larvae, Vernon, B.C., October 13, 1959 (Condrashoff) in the United States National Museum, Washington, D.C.

Contarinia constricta new species

Male:—Body length 1.79 (1.66-1.92) mm. excluding terminalia. Antenna 1.84 mm. long. Basal segment of palpus angular, 1¾ times longer than broad; second segment 1⅓ times longer and broader than basal segment; third segment slightly narrower and 1½ times longer than second; apical segment cylindrical, 1⅓ times

Figs. 10-24. 10. Fifth antennal segment of *Contarinia pseudotsugae* (female). 11. Fifth antennal segment of *C. pseudotsugae* (male). 12, 13. Prothoracic tarsus of *C. pseudotsugae* (ventral and lateral aspects). 14-15. Prothoracic tarsus of *C. cuniculator* (lateral and ventral aspects). 16-20. Terminalia. 16, 17. *C. pseudotsugae*. 18. *C. constricta*. 19. *C. cuniculator*. 20. Terminal claw on dististyle of *C. pseudotsugae*. 21-24. Tip of ovipositor. 21. *C. pseudotsugae* (dorsal aspect). 22. *C. pseudotsugae* (lateral aspect). 23. *C. cuniculator* (dorsal aspect). 24. *C. cuniculator* (lateral aspect).


10
11
12
13
14
15
16
17
18
19
20
21
22
23
24

longer than third segment (Fig. 7). Thorax yellowish-brown, 0.72 mm. long. Wing 2.00 mm., long, 0.82 mm. broad. Length of legs as follows: prothoracic, 2.70 mm.; mesothoracic, 2.64 mm.; metathoracic, 3.25 mm. Abdomen deep orange or red, 1.07 mm. long, excluding terminalia. Terminalia (Fig. 18) with dorsal plate bilobed, gently emarginate with a shallow basally rounded cleft; tips of lobes rounded. Ventral plate bilobed, each lobe three times as long as broad, cleft extending far cephalad of cleft of dorsal plate. Style narrow. Other characteristics similar to *C. pseudotsugae*.

Female:—Body length 2.13 (1.83-2.24) mm., excluding ovipositor. Antenna 1.14 mm. long. Palpus as in male. Thorax yellowish-brown, 0.72 mm. long. Wing 2.29 mm. long, 0.89 mm. broad. Leg lengths as follows: prothoracic, 2.48 mm.; mesothoracic, 2.43 mm.; metathoracic, 2.91 mm. Abdomen dark orange, length 1.42 mm. excluding ovipositor. Other characteristics as in *C. pseudotsugae*.

Holotype:—Male, Oyama, British Columbia, Canada, May 8, 1959 (Condrashoff), reared from larva from needle of Douglas fir, *Pseudotsuga menziesii* (Mirb.) Franco. Type number 7115 in the Canadian National Collection, Ottawa, Canada.

Allotype:—Female, same data as holotype.

Paratypes:—Two males, two females, same data as holotype; one male pupa, Oyama, B.C., March 29, 1959; two female pupae, Oyama, B.C., March 20, 1959; one female pupa, Oyama, B.C., March 29, 1959; five instar II larvae, Vernon, B.C., August 22, 1959; five instar III larvae, Vernon, B.C., October 13, 1959 (Condrashoff), in the Canadian National Collection, Ottawa. Two males, one female, same data as holotype; five instar II larvae, Vernon, B.C., August 22, 1959; five instar III larvae, Vernon, B.C., October 13, 1959 (Condrashoff), in the Barnes Collection, Rothamsted Experimental Station, Harpenden, Herts., England. Five instar II larvae, Vernon, B.C., August 22, 1959; five instar III larvae, Vernon, B.C., October 13, 1959 (Condrashoff), in the United States National Museum, Washington, D.C.

Contarinia cuniculator new species

Male:—Body length 1.67 (1.41-1.86) mm. excluding terminalia. Antenna 1.93 mm. long. Basal segment of palpus (Fig. 8) 1½ times longer than wide, spindle-shaped; second segment with proportions similar to first, but more rounded; third segment clavate, 1⅓ times longer than and four-fifths as broad as second segment; apical segment cylindrical, slightly narrower and 1⅓ times longer than third segment. Thorax brown, 0.58 mm. long. Wing 1.90 mm. long, 0.69 mm. broad; second vein close to costa, joining costa gradually. Length of legs as follows; prothoracic, 2.51 mm.; mesothoracic, 2.40 mm.; metathoracic, 2.83 mm. Empodium rounded at apex, tapering to base of claws (Figs. 14, 15). Abdomen amber, 1.07 mm. long, excluding terminalia. Terminalia (Fig. 19) with dorsal plate bilobed, with a wide and deep V-shaped cleft. Ventral plate bilobed, each lobe three times as long as broad, cleft extending a short distance below cleft of dorsal plate. Style moderately broad. Other characteristics similar to *C. pseudotsugae*.

Female (Fig. 4):—Body length 1.67 (1.54-1.73) mm. excluding ovipositor. Antenna 0.97 mm. long. Palpus as in male. Thorax brown, 0.57 mm. long. Wing 1.88 mm. long, 0.70 mm. broad. Length of legs as follows: prothoracic, 2.02 mm.; mesothoracic, 1.96 mm.; metathoracic, 2.41 mm. Tarsi as in male. Abdomen dark orange to reddish; dorsum and venter of segments dusky, posterior margins dark; length 1.12 mm. excluding ovipositor. Base of ovipositor (Fig. 5) slightly expanded, with a darkly pigmented, anteriorly bifurcate patch on dorsum.

Tip of ovipositor (Figs. 22, 24) bilobed, heart-shaped, 1.1 times longer than broad, with prominent setae. Other characteristics as in *C. pseudotsugae*.

Holotype:—Male, Oyama, British Columbia, Canada. April 28, 1959 (Condrashoff), reared from larva from needle of Douglas fir, *Pseudotsuga menziesii* (Mirb.) Franco. Type number 7116 in the Canadian National Collection, Ottawa, Canada.

Allotype:—Female, Oyama, B.C., April 24, 1959.

Paratype:—Three males, Oyama, B.C., April 22, 24 and 27, 1959; three females, Oyama, B.C., March 18, April 24 and 29, 1959; three female pupae, Oyama, B.C., March 20 and 27 and April 1, 1959; five instar II larvae, Vernon, B.C., August 22, 1959; five instar III larvae, Vernon, B.C., October 13, 1959 (Condrashoff), in the Canadian National Collection, Ottawa. Two males, Oyama, B.C., April 24 and 29, 1959; two females, Oyama, B.C., April 23 and 29, 1959; five instar II larvae, Vernon, B.C., August 22, 1959; five instar III larvae, Vernon, B.C., October 13, 1959 (Condrashoff), in the Canadian National Collection, Ottawa. Two males, Oyama, B.C., April 24 and 29, 1959; two females, Oyama, B.C., April 23 and 29, 1959; five instar II larvae, Vernon, B.C., August 22, 1959; five instar III larvae, Vernon, B.C., October 13, 1959 (Condrashoff), in the Barnes Collection, Rothamsted Experimental Station, Harpenden, Herts., England. One male, Oyama, B.C., April 21, 1959; one female, Oyama, B.C., April 23, 1959; five instar II larvae, Vernon, B.C., August 22, 1959; five instar III larvae, Vernon, B.C., October 13, 1959 (Condrashoff), in the United States National Museum, Washington, D.C.

Species Differences and Generic Relationship

Males of the needle-inhabiting *Contarinia* are easily distinguished by differences in construction of the terminalia. In *C. pseudotsugae* the dorsal plate is abruptly emarginate and the cleft is deep and rounded basally; the lobes are truncate. The lobes of the ventral plate are about twice as long as broad. The style is moderately broad. The dorsal plate in *C. constricta* is gently emarginate with a shallow rounded cleft. The lobes of the ventral plate are long and narrow, about 3 times longer than broad. The style is narrow. In *C. cuniculator* the dorsal plate has a wide, deep, V-shaped cleft. The tip of the ovipositor in females of *C. cuniculator* is short and heart-shaped, while that in *C. pseudotsugae* and *C. constricta* is longer and bullet-shaped; also *C. cuniculator* bears, at the base of the ovipositor, a dark bifurcate patch which is absent in the other two species. The females of *C. constricta* may be distinguished from *C. pseudotsugae* on the basis of their much larger abdomen and by the cylindrical apical segment of the palpus. The apical segment of the palpus in *C. pseudotsugae* is usually irregular in shape.

This group of *Contarinia* species is atypical of the genus, as the ovipositor in the females is thick and fleshy, with a relatively blunt point, and the third vein of the wing unites with the margin beyond the apex. According to Felt's key (1925) the ovipositor in the genus *Contarinia* is long and slender, and the third vein of the wing unites with the margin at the apex. Barnes (in litt.) recommended the species be placed in *Contarinia* on the basis of their otherwise close affinities with this genus.

Monzen (1955) describes a pine-bud midge from Japan, *C. matusintome* Haraguti & Monzen, that resembles the species from Douglas-fir needles in the structure of the ovipositor. *Contarinia oregonensis* Foote (Foote, 1956) from Douglas-fir cones is distinct from the needle-infecting species; the dististyle in the male is slender and the lobes of the dorsal plate are broad and rounded; the ovipositor in the female is slender and the tip is needle-like.

Summary

Three new species of gall midge, *Contarinia pseudotsugae*, *C. constricta*, and *C. cuniculator* are described and figured. These are closely related species whose larvae feed in needles of Douglas fir in British Columbia and western United States.

Acknowledgments

The author wishes to express his appreciation to Dr. D. A. Ross, Officer-in-Charge of the Forest Biology Laboratory, Vernon, B.C. and Mr. R. R. Lejeune, Officer-in-Charge of the Forest Biology Laboratory, Victoria, B.C., for their helpful advice and criticisms in the preparation of the manuscript. Thanks are due to the late Dr. H. F. Barnes, Rothamstead Experimental Station, Harpenden, Herts., England for his helpful suggestions, and to Dr. J. R. Vockeroth, Entomology Research Institute, Ottawa, Ontario for critical examination of the species descriptions.

References

Barnes, H. F. 1951. Gall midges of economic importance. Vol. V. London.

Denton, R. E. 1954. Midge damage affects Christmas-tree production in the Inland Empire. *U.S. Dept. Agric. For. Ser. Res. Note No.* 7, pp. 1-4.

Felt, E. P. 1925. Key to gall midges. *Bull. N.Y. State Mus. No.* 257: 1-227.

Felt, E. P. 1940. Plant galls and gall makers. Comstock Pub. Inc. N.Y., 364 pp.

Foote, R. H. 1956. Gall midges associated with cones of western forest trees (Diptera: Itonididae) *J. Wash. Acad. Sci.* 46: 48-57.

Monzen, K. 1955. Some Japanese gallmidges with descriptions of known and new genera and species (II) (Diptera, Cecidomyidae). *Ann. Rep. Gakugei Fac. Iwate Univ.*, Vol. 9, 1955, pt. 2.

(Received May 19, 1960)

Life-History and Habits in Newfoundland of *Swammerdamia lutarea* (Haw.) (Lepidoptera: Yponomeutidae), a Pest New to North America[1]

By Ray F. Morris

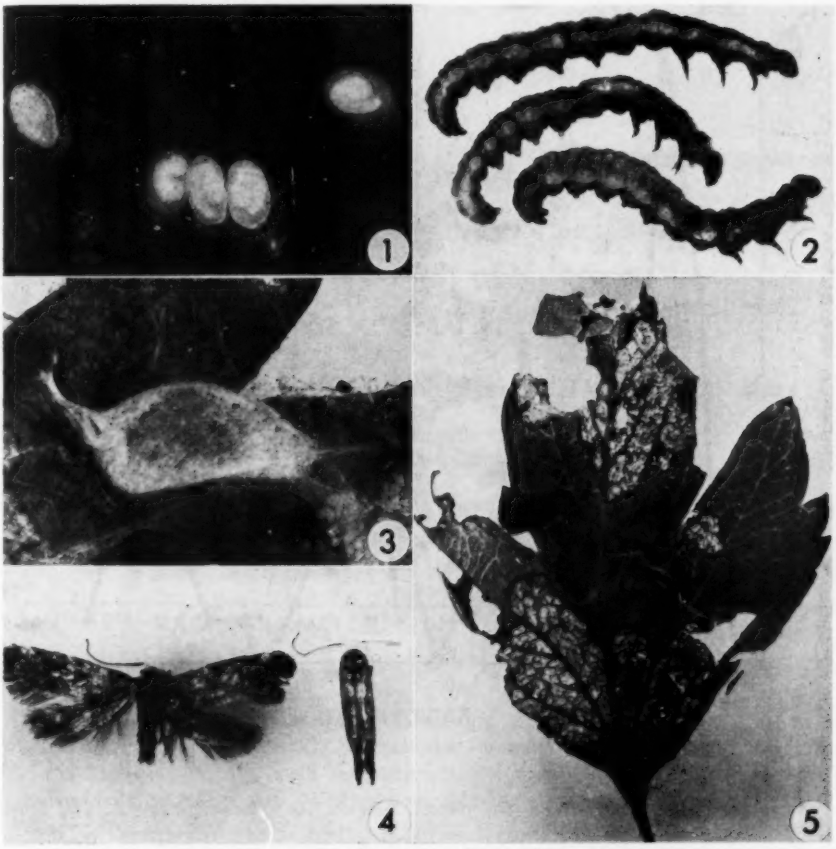
Experimental Farm, St. John's West
Newfoundland, Canada

Introduction

In June, 1954, hawthorn trees and shrubs in St. John's, Newfoundland, were severely attacked by small leaf-eating caterpillars. Larvae were taken from a hawthorn tree, *Cratageus* sp., at Bowring Park, St. John's West, during the first week of July, 1954, and reared in the laboratory. Moths that emerged were identified as of *Swammerdamia lutarea* (Haw.) by Dr. T. N. Freeman, Entomology Research Institute, Canada Department of Agriculture, Ottawa, who also noted (in litt.) that this was apparently the first record of the species in North America. Dr. L. G. Davis (in litt.), Economic Insect Survey Section, United States Department of Agriculture, Washington, D.C., later confirmed this observation. *Swammerdamia lutarea* is now common throughout St. John's and has also been found at Brigus, approximately 50 miles to the west.

According to Eckstein (1933, p. 177), *S. lutarea* is found throughout Central Europe, and Stainton (1859, p. 306) and Parfitt (1878, p. 556) recorded its occurrence in England. It is presumably not an abundant or serious pest in Europe since no reference to its economic importance was found in the literature.

[1]Contribution No. 2, Experimental Farm, Research Branch, Canada Department of Agriculture, St. John's West, Newfoundland.



Figs. 1-5. *Swammerdamia lutarea* (Haw.). 1, Eggs, x 30; 2, Fourth-instar larvae, x 6; 3, Cocoon, x 4; 4, Adult moths at rest and with wings spread, x 4; 5, Injured leaf showing skeletonizing effect of larval feeding, x 3.

A common name for *S. lutarea* is not given in the list of approved names of the Association of Applied Biologists (1952), but Parfitt referred to it as the yellowish ermine. Locally, it is commonly called the hawthorn webworm.

This paper is a report on the life-history and habits of *S. lutarea* as found in hawthorn hedges and trees in St. John's during the period 1957-59.

Host Plants

Larvae of *S. lutarea* were observed feeding on all locally grown varieties of hawthorn, *Crataegus oxyacantha* L. and *C. bedicellata* Sarg. According to Meyrick (1927, pp. 735-736), *S. lutarea* is also found on *Sorbus aucuparia* L., the European mountain-ash.

Description, Life-History, and Habits

Only one generation of this species develops annually in Newfoundland. The female moth deposits her eggs singly, or in groups of two and three on the upper surface of the leaf, usually on the midrib and its lateral branches. Occasionally, eggs are laid on the undersurface of the leaf.

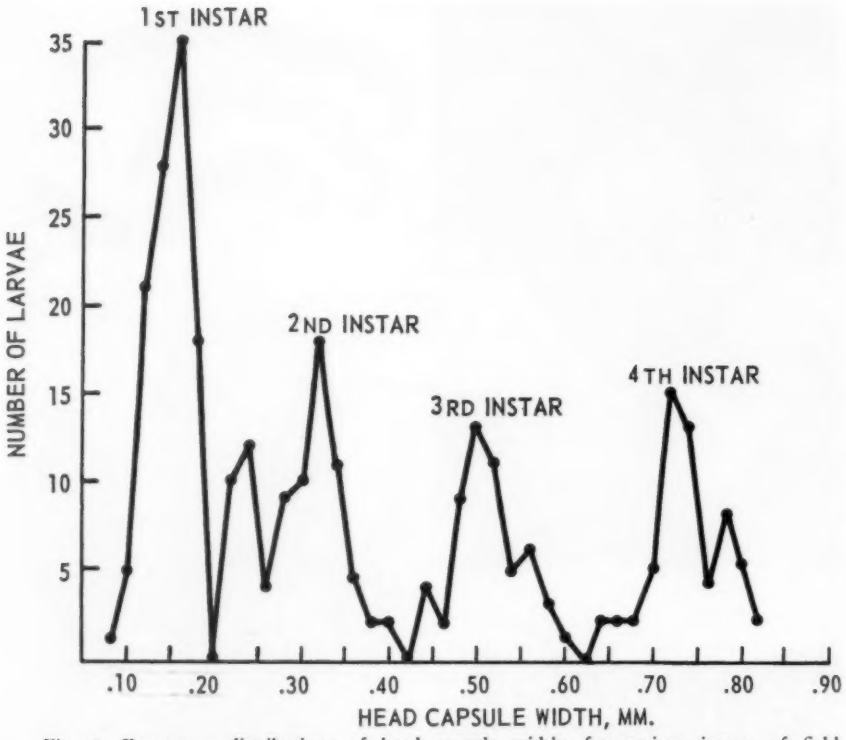


Fig. 6. Frequency distributions of head capsule widths for various instars of field collected larvae.

Oviposition occurs during the period August 10 to September 5. The eggs (Fig. 1) are oval in outline and somewhat flattened, with a translucent reticulate margin. They are yellow with a faint greenish tinge. Length of 35 eggs varied from 0.37 to 0.58 mm. and the width from 0.22 to 0.37 mm. Eggs hatched within 12 to 28 days after oviposition, the long period of incubation being due to the low temperatures that are common during the latter part of August and early September. In a heavy infestation, numbers of eggs on individual leaves varied from 1 to 14, averaging 6.9.

The first-instar larvae are creamy white, have a dark-brown head capsule when newly hatched, and are 0.8 to 1.4 mm. long. Head capsules vary in width from 0.12 to 0.18 mm. averaging 0.15 mm. (Fig. 6). As soon as the larva hatches, it eats a hole through the upper leaf surface and feeds as a miner between the upper and lower epidermal layers. This is apparently the first observation of the mining habit of *S. lutarea* as no mention of this was found in the European literature. It feeds in this manner until mid-October and then eats a small round hole through the upper epidermis and moves to the crotches of the twigs. Here it overwinters after completely enveloping itself in a white silken hibernaculum. The larva is then medium brown dorsally with two lighter dorso-longitudinal lines. Ventrally, it is creamy white with a mid-ventral brown line. The head capsule is black. In early June, when new leaves appear on the hawthorns, overwintered larvae leave the hibernacula and resume feeding. They web the leaves and flower buds loosely together.

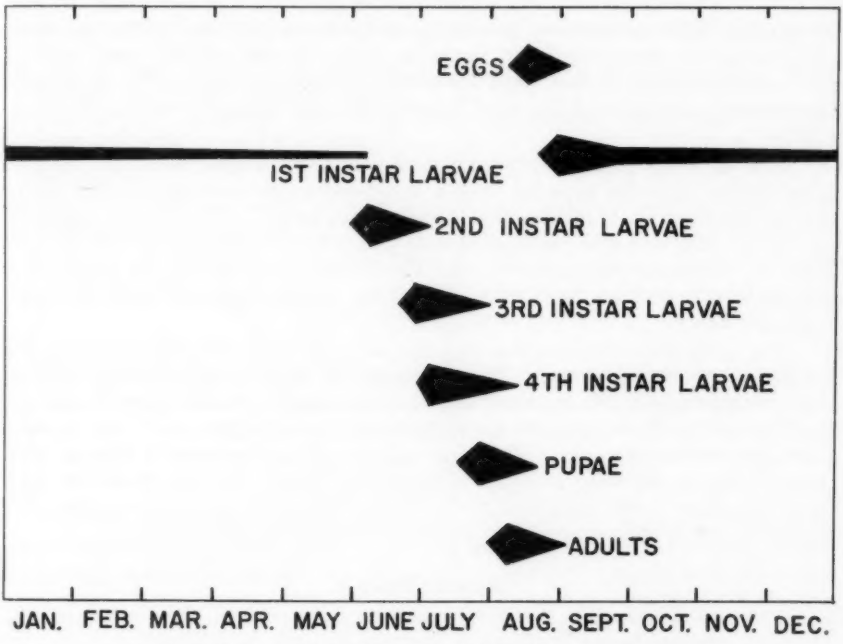


Fig. 7. Diagram of life-history of *S. lutarea* in Newfoundland.

The second-instar larvae are approximately 2.5 to 5.0 mm. long. The head capsules range in width from 0.22 to 0.38 mm., averaging 0.28 mm. (Fig. 6). The head is dark brown with black markings and the abdomen is reddish-brown with longitudinal lighter stripes, each segment bearing a number of long prominent setae. After the first ecdysis, larvae become very active and wriggle vigorously when disturbed and it is at this stage that they begin feeding voraciously and damage becomes quite noticeable.

The third-instar larvae, approximately 6.0 to 8.5 mm. long, are active from June 23 to July 31. The head capsules range in width from 0.44 to 0.58 mm. averaging 0.51 mm. (Fig. 6). The head is dark brown and the abdomen reddish-brown with lighter longitudinal lateral stripes.

The fourth-instar larvae (Fig. 2) are approximately 9.0 to 11.5 mm. long and are active from June 27 to August 15 (Fig. 7). The head capsules range in width from 0.64 to 0.82 mm. averaging 0.74 mm. (Fig. 6). The head capsule is brown overlaid with a darker pattern. The prothorax is heavily sclerotized with yellow and black markings. The abdomen is dark brown dorsally and ventrally and has a spiracular stripe, which is yellow posteriorly and white anteriorly. Dorsally, two narrow yellow stripes, separated by a narrow mid-dorsal darker line, run the entire length of the abdomen. White-ringed pinacula are prominent on each segment and bear one or two long setae.

The second-, third-, and fourth-instar larvae feed on the upper epidermis and parenchyma cells of webbed leaves. The lower epidermis withers and turns brown, giving the leaf a very noticeable skeletonized effect (Fig. 5). When leaves are webbed closely together, the larvae may eat the lower epidermis and leave the upper epidermis to dry and wither.

Data on the number of larval instars and the occurrence of each were obtained by making field observations at weekly intervals in 1957 and 1959, and daily observations on insectary-reared larvae in 1958. A total of 323 head capsules from field-collected larvae were measured throughout 1958. The frequency distributions of widths of the head capsules for the various instars are shown in Fig. 6.

Pupation takes place during the period July 23 to August 20 (Fig. 7), in the larval habitat after the larva has spun a dense white cocoon which is attached to the leaf surface (Fig. 3) or between dried leaves or twigs. The cocoon is approximately 8-9 mm. long and has pointed ends where it is attached to the leaf surface. Pupation commences immediately after the cocoon is completed, the pupa being greyish-brown and 4-5 mm. long. The eyes, caudal segments, and cremaster hooks are black.

The adult (Fig. 4) emerges during the period July 31 to September 4 and has a wing expanse of 10-13 mm. The vertex of the head is conspicuously marked with a tuft of long white scales. The thorax and wings are dark grey with white flecking and the forewing has a dark transverse band near the centre and a white costal spot before the apex. The inner margin of the hindwing is fringed with setae as long as the wing is wide. The fuscous thorax and the transverse dark band extending to the margin of the forewing separate *S. lutarea* from the other European and American species of *Swammerdamia* (Meyrick 1927).

Natural Control

This insect appears to be free from natural enemies in Newfoundland. In 228 field collected larvae in 1958 and 50 pupae in 1959, no evidence of parasitism was found.

Economic Importance

Repeated attacks on hawthorn shrubs and trees since 1954 have caused high mortality in these ornamental plants in St. John's. However, the pest only attacks plant species of limited local value and is not at present considered to be a serious economic threat. Nevertheless, it deserves close watching because of possible spread to related species of economic importance elsewhere.

Summary

The European yponomeutid *Swammerdamia lutarea* (Haw.) has become an established pest on ornamental hawthorns in St. John's, Newfoundland. Only one generation a year was observed. The insect passes the winter as a first-instar larva in a hibernaculum on the twigs and emerges to feed on foliage in early June. There are four larval instars. Pupation occurs in the larval habitat during the period July 23 to August 20. Adults emerge from July 31 to September 4 and eggs are laid on leaves from August 10 to September 5. Eggs hatch in 12 to 28 days and the young larvae bore directly into the leaves and feed as miners until they move to the twigs to overwinter. No parasites were reared from over 200 field-collected larvae and pupae.

Acknowledgments

Thanks are due to Dr. W. J. Hall, Commonwealth Institute of Entomology, London, England, for supplying references and to Mr. John Carter, technician, for his assistance in making field observations, insectary rearing, and keeping records.

References

Association of Applied Biologists. 1952. Common names of British insects and other pests. Part Two. London, England.

Eckstein, K. 1933. Die Schmetterlinge Deutschlands. 5. Die Kleinschmetterlinge Deutschlands. K. G. Lutz Verlong, Stuttgart.

Meyrick, E. 1927. A revised handbook of British Lepidoptera. Watkins and Doncaster, London, England.

Parfitt, E. 1878. The fauna of Devon: Lepidoptera. Rept. Devonshire Assoc. Advance. Sci. 10: 310-588.

Stainton, H. T. 1859. A manual of British butterflies and moths. Vol. II. J. Van Voorst, London.

(Received June 30, 1960)

The Distribution, Life History, and Economic Importance of the Winter Moth, *Operophtera brumata* (L.) (Lepidoptera, Geometridae) in Nova Scotia[1]

By F. G. CUMING
Forest Biology Laboratory Truro, N.S.

In the early 1930's defoliation of red oak, *Quercus rubra* L., white elm, *Ulmus americana* L., apple, *Malus* spp., and other deciduous trees in the South Shore region of Nova Scotia was attributed to the fall cankerworm, *Alsophila pometaria* (Harr.), and the spring cankerworm, *Paleacrita vernata* (Peck). The identity of the latter was questioned when adults occurred in the fall. These adults were subsequently identified as *Operophtera brumata* (L.), the winter moth (Hawboldt and Cuming, 1950; Smith, 1950).

O. brumata is not known to occur elsewhere in North America. There is little doubt that it was introduced from Europe and has been present in Nova Scotia for 30 or more years. This paper presents the distribution, life history, and habits of *O. brumata* and the effect of defoliation on red oak trees in Nova Scotia. The life histories in Nova Scotia and in Europe are compared.

Distribution and Hosts

Detailed descriptions of distribution have been given since 1950 in the Annual Report of the Forest Insect and Disease Survey. The known distribution in 1950 is compared with that in 1959 in Fig. 1. During the 10-year period the infested area has gradually increased except for a small area in Digby County where the insect was recorded in 1950 but has not been found since.

The most common tree hosts in order of severity of attack are: apple; red oak; white elm; red maple, *Acer rubrum* L.; basswood, *Tilia americana* L.; and ironwood, *Ostrya virginiana* (Mill.) K. Koch. Other hosts are: birches, *Betula* spp.; poplars, *Populus* spp.; willows, *Salix* spp., and many other deciduous species. This insect does not normally feed on conifers, but occasional larvae that evidently dropped from red oak or maple trees, fed on new shoots of white spruce, *Picea glauca* (Moench) Voss.

Description of Stages

Descriptions of immature stages were made from field-collected material and compared with material from Europe. No differences were found.

[1]Contribution No. 652, Forest Biology Division, Research Branch, Department of Agriculture, Ottawa, Canada; in part from a thesis submitted in partial fulfilment of the requirements for the degree of Master of Science, Dalhousie University, 1958.

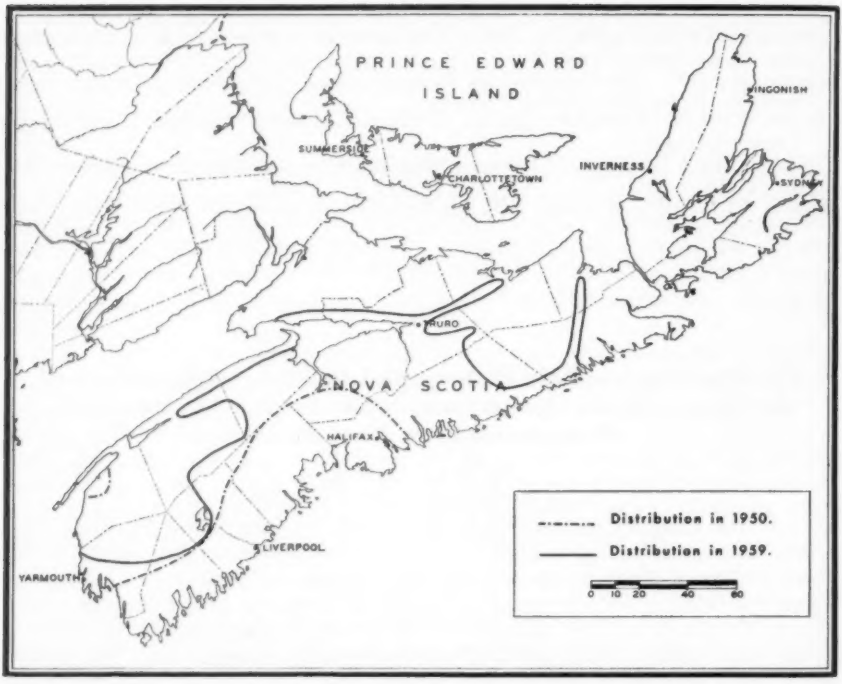


Fig. 1. Map showing distribution of *O. brumata* in Nova Scotia in 1950 and 1959.

Egg

Ovoid; surface with minute, roughly pentagonal pits; light green when first laid, changing to orange, then to dark bluish green; width .42 mm., length .70 mm.

Late-instar Larva

Head light brown with chestnut brown patches; body green, mid-dorsal line dark green and narrow, three pairs of creamy yellow latero-dorsal stripes from prothorax to eighth abdominal segment; one pair of ventral prolegs.

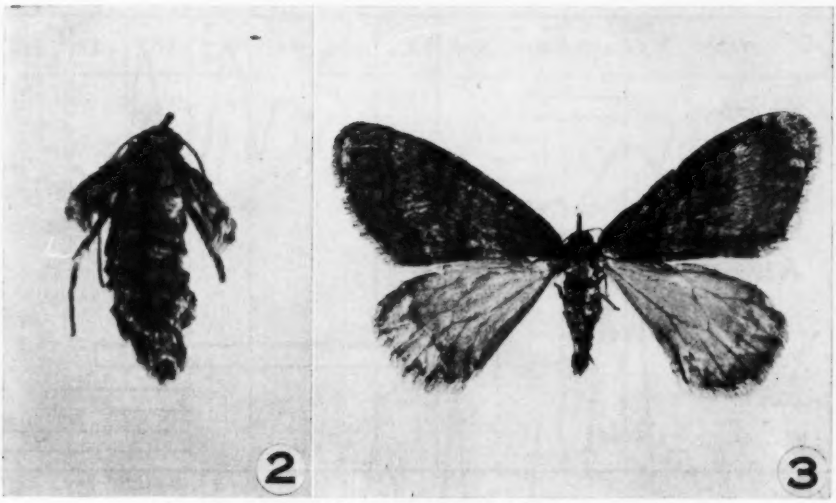
Pupa

Obtect, tawny brown; abdominal terga 3 to 7 with shallow circular pits, more numerous on segments 6 and 7; cremaster with two broadly divergent, short spines; width 2.6 mm., length 7.0 to 7.6 mm.

Adult

Female (Fig. 2): Head brown to black; eyes black; antennae filiform, silver grey flecked with black; body dusky brown to silver grey with occasional irregular black spots; wings vestigial, forewings white with two black bands, 2.0 to 3.2 mm. long; overall length 6.0 to 8.0 mm.; width of abdomen 2.0 to 3.5 mm.

Male (Fig. 3): Head dark brown, eyes black; antennae tawny brown, more or less serrated; body dusky brown spotted with black; forewings dusky brown with obscure markings, hind wings slightly paler, spread 27.0 to 30.0 mm.; length 8.0 to 9.0 mm.



Figs. 2 and 3. *O. brumata* adults. 2, female. 3, male.

Life History and Habits

O. brumata has one generation per year and normally overwinters as an egg (Fig. 4). Hatching occurs from late April to late May. Larvae feed until the last half of June when they drop to the ground and pupate. The adults emerge between late October and mid-December, with a peak during the third week of November.

Egg

The eggs are light green when first laid, turn orange between 10 and 14 days after oviposition and just prior to hatch become dark bluish green. Hatch began between April 22 and May 11 and ended beween May 12 and 29 in the years 1956 to 1959 (D. G. Embree, private communication).

Larva

Measurements of larval head capsules indicated five instars:

Measurements of larval head capsules indicated five instars:

Material examined		Head width (mm.)	
Instar	Number	Mean	Range
1	90	0.25	0.21 – 0.25
2	57	0.40	0.39 – 0.42
3	61	0.62	0.56 – 0.67
4	55	0.96	0.88 – 1.05
5	42	1.56	1.51 – 1.61

Individual insectary rearings of 44 larvae showed that the mean number of days spent in each instar beyond the first was 4.0, 4.3, 5.0, and 7.7. Twice-weekly collections at Jollimore in 1953 indicated the duration of each larval instar in the field (Fig. 4). The degree of development varied with locality; for example, larvae at Port Mouton, Queens County, were six days further advanced than those at Jollimore, Halifax County.

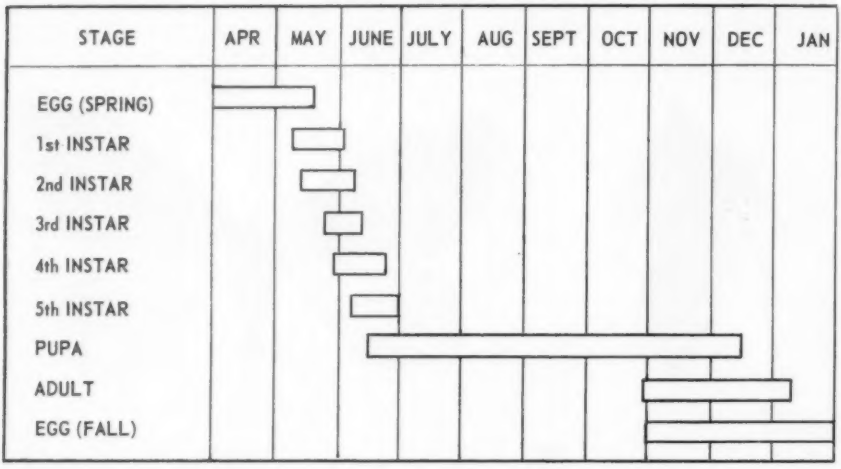


Fig. 4. Life history chart for *O. brumata*, 1953.

First-instar larvae feed on the opening buds but drift with the wind elsewhere on silken threads if the buds are closed. Newly hatched larvae can live for five days with no food. After the buds open the larvae feed from the underside of the leaves which, except the main veins, are completely eaten. Fourth-instar larvae feed inside loose leaf rolls. Fifth-instar larvae feed for two or three days, fast for about five, then drop to the ground. They form earthen cells beneath the surface in which they remain in a prepupal state for about six days.

Pupa

Pupation takes place during late June and early July. Pupae were found approximately five inches deep in rocky soil but only two inches deep or less in fine soil. Schneider-Orelli (1932) occasionally found pupae in trees in Switzerland.

Adult

In Canada emergence occurs from late October to mid-December. It has occurred as late as the end of January in England (Jary, 1931), and occasionally not until spring in parts of Russia (Schreiner, 1916; Machotin, 1936). Males appear three or four days earlier than females. Of 1,800 late-instar larvae reared in 1951, 540 females and 273 males emerged giving a sex ratio of 0.66. Emergence tends to reach a peak during the third week of November. However, heavy snowfalls hamper emergence and change the pattern. Freezing temperatures inhibit emergence, once begun (Figs. 5 and 6).

Adults are inactive during daylight. The flight of males generally begins one-half hour after sunset although on overcast days they may become active before dusk. Also in the evening the females climb tree trunks and other objects near their emergence sites.

Caged adults mated between 5:30 p.m. and 11:05 p.m. and paired adults remained in coition from 75 minutes to over five hours. Copulation can occur at sub-freezing temperatures; mating occurred at air temperatures between 30.6°F. and 54.0°F. Females frequently mate twice and one was seen to mate three times. Males, too, may mate more than once and Speyer (1938) stated that one male can mate seven females.

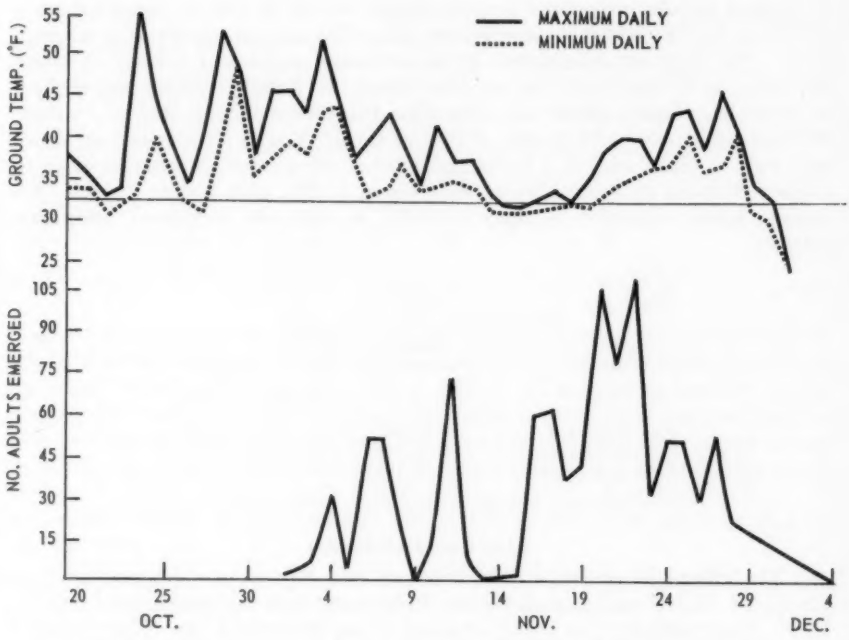


Fig. 5. Daily emergence of *O. brumata* and ground temperatures, 1952.

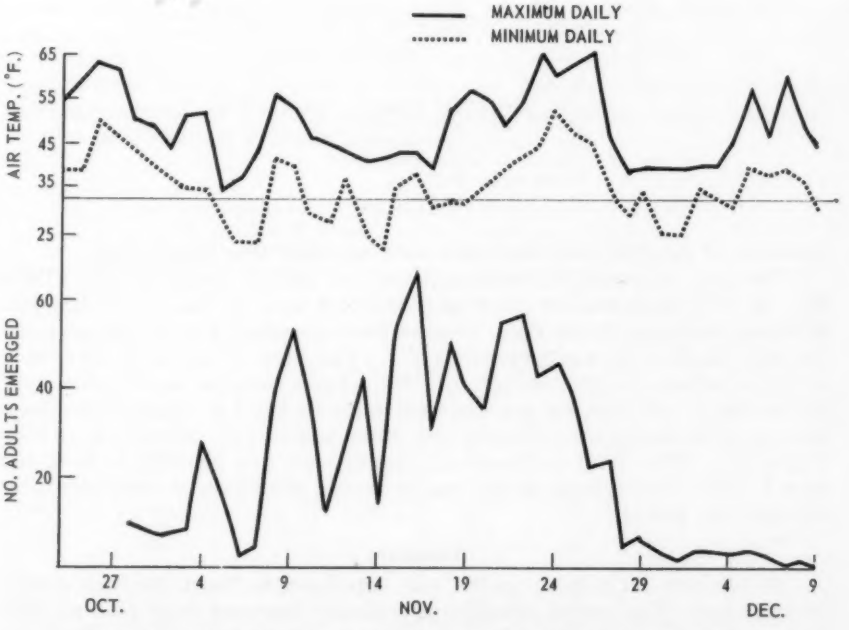


Fig. 6. Daily emergence of *O. brumata* and air temperatures, 1953.

Caged females oviposited from 3:15 p.m. to 12:20 a.m. at temperatures of 29.1°F. to 54.0°F., which shows they are able to lay eggs at sub-freezing temperatures. The eggs are usually laid in bark crevices and under lichens on trunks and branches of host trees, but are also commonly found in empty egg shells of *A. pometaria* (Smith, 1958), and other sites that afford suitable shelter. Usually they are laid singly or in groups of two or three. Caged females laid up to 350 eggs with a mean of 154 (Table I). Counts of discernible oocytes from 50 virgin females in 1952 and 1953 varied from 90 to 381, with a mean of 205. The average female dissected by Speyer (1939) in Germany contained 300 mature oocytes.

TABLE I

Observations on Fecundity of 39 *O. brumata* Females, 1952 and 1953.

	Total	Range	Mean
Eggs deposited	5,996	0 – 350	153.7
Oöcytes remaining	1,144	0 – 316	29.3
Eggs plus oöcytes	7,140	72 – 351	183.1

Effect of Defoliation

The effects of repeated defoliation on tree vigour were studied on three groups of 50 red oak trees between Bridgewater and Liverpool from 1952 to 1956. Two plots were in lightly stocked young stands and one (Plot 3) was in a stand of mixed ages where pole-size trees predominated. The tree crowns were classified as follows:

Class	Condition
1	Normal
2	Thin on top, dead twigs, no dead branches.
3	Several small branches dead.
4	Less than half branches dead.
5	More than half branches dead.
6	Whole crown dead.

Estimates of defoliation for each tree were recorded after larval drop.

The most severe defoliation occurred in 1953 and the lightest in 1954 (Table II). In 1952, from 38 to 78 per cent of the trees were in class 3 with very few in worse condition (Table III). Normal trees comprised 8 to 32 per cent and the mean classification was between 2 and 3. The effect of the severe defoliation in 1953 is reflected in the tree tally of 1954. There were no normal trees, very few in class 2, and 90 to 100 per cent were in classes 3 and 4. Further deterioration occurred during the following two years, and in 1956, all trees were class 3 or worse. Trees with dead crowns (class 6) were first recorded in 1956, and were a result of an average 60 per cent or greater defoliation of these trees over the five-year period.

Summary

O. brumata, a European species, was introduced to North America at least 30 years ago. The known distribution gradually increased from 1950 to 1959. Its hosts include: apple, red oak, and many other deciduous species. Brief des-

TABLE II

Per cent Defoliation of Red Oak Trees by *O. brumata* from 1952 to 1956.

Year	Oak Hill (Plot 1)	Big Hill (Plot 2)	Hebbs Cross (Plot 3)
1952	65	60	60
1953	84	71	93
1954	29	22	47
1955	46	24	60
1956	54	33	80

criptions of all stages are included. Its life history in Nova Scotia is similar to that in Western Europe. It has one generation per year and overwinters in the egg stage. Hatch occurs in late April and May. First-instar larvae feed on the opening host buds; later instars completely consume the leaves. In late June the fifth-instar larvae drop to the ground and pupate in the soil. Emergence occurs from late October to mid-December. In the evening the males take flight and the females climb the tree trunks where mating occurs. Females lay about 150 eggs singly, usually in bark crevices, under lichens, and other sheltered sites on the host trees.

Analyses of plot records for the period 1952 to 1956 show that red oak stands gradually deteriorate and trees die from repeated defoliation.

Acknowledgments

Valuable suggestions and advice were given by R. E. Balch and R. S. Forbes, Forest Biology Laboratory, Fredericton, N.B., and W. A. Reeks, Forest Biology Laboratory, Winnipeg, Man. D. G. Embree, Forest Biology Laboratory, Truro, L. S. Hawboldt, Nova Scotia Dept. of Lands and Forests, Halifax, and C. C. Smith, Forest Biology Laboratory, Fredericton, assisted with the field work. European material was supplied by H. G. Wylie, Entomology Research Institute for Biological Control, Belleville, Ont.

TABLE III

Percentages of Red Oak Trees in Various Crown Classes in *O. brumata* Defoliation Plots in 1952, 1954, and 1956.

		Percentage of trees falling into class					
		1	2	3	4	5	6
Plot 1	1952	8	6	78	8		
	1954		5	74	21		
	1956			62	34	4	
Plot 2	1952	32	26	38	2	2	
	1954			94	6		
	1956			90	10		
Plot 3	1952	22	26	42	8	2	
	1954		4	60	30	6	
	1956			76	16	4	4

References

Hawboldt, L. S., and F. G. Cuming. 1950. Cankerworms and European winter moth in Nova Scotia. *Can. Dept. Agric., For. Biol. Div., Bi-Mon. Progr. Rept.* 6(1).

Jary, S. G. 1931. Some observations on winter moth caterpillar attack on fruit trees in 1929-1930. *J. Southeastern Agr. Coll., Wye, Kent*, 28: 137-146.

Machotin, A. 1936. Zu den Reduktionserscheinungen in der Morphologie des erwachsenen Frostspanners (*Operophtera brumata* L.). *Compt. Rend. Acad. Sci. U.R.S.S.* 2: 401-404.

Schneider-Orelli, O. 1932. Weitere Versuche mit Frostspannerpuppen, *Operophtera brumata* L. *Mitt. Schweizerischen Ent. Ges.* 15: 266-268.

Schreiner, J. F. 1916. *Cheimatobia brumata* L. and its control. *Memoirs of the Bureau of Entomology of the Scientific Committee of the Ministry of Agriculture, Petrograd* 6. [in Russian] (*Rev. Appl. Ent.*, A, 4: 141.)

Smith, C. C. 1950. Notes on the European winter moth in Nova Scotia. *Can. Dept. Agric., For. Biol. Div., Bi-Mon. Progr. Rept.* 6(2).

Smith, C. C. 1958. A note on the association of fall cankerworm (*Alsophila pometaria* (Harr.)) with winter moth (*Operophtera brumata* (Linn.)) (Lepidoptera : Geometridae). *Canadian Ent.* 90: 539-540.

Speyer, W. 1938. Beiträge zur Biologie des Kleinen Frostspanners (*Cheimatobia brumata* L.). Das Ausschlüpfen der Raupen und der Flug der Falter unter Berücksichtigung innerer und äusserer Faktoren. *Z. Pflkrankh.* 48: 449-471.

Speyer, W. 1939. Neuere Feststellungen über die Biologie des Kleinen Frostspanners *Cheimatobia brumata* L. *Verhandl. 7. int. Kongr. Ent., Berlin*, 1938, 4: 2419-2435.

(Received June 3, 1960)

Anthophora occidentalis Cress. (Hymenoptera: Apidae) and Its Associates at a Nesting Site in Southern Alberta[1]

By G. A. Hobbs[2], W. O. Nummi[3], and J. F. Virostek[3]

Research Station, Canada Department of Agriculture
Lethbridge, Alberta

Studies on the ecology of *Megachile perihirta* Ckll. (Hymenoptera: Megachilidae), a leaf-cutter bee that is a valuable pollinator of alfalfa in southern Alberta, indicated that the pillager (depredator) *Nemognatha lutea* Lec. (Coleoptera: Meloidae) and the parasite *Dasymutilla fulvohirta* (Cress.) (Hymenoptera: Mutillidae) have other hosts besides *M. perihirta* (Hobbs, 1956). Adults of both species at the nesting habitat of a population of *M. perihirta* have been too numerous to have come solely from the cells of *M. perihirta*; also, the wide range in size of the adults of *N. lutea* indicated that other insects also served as hosts for this species. Mickel (1928, 1928a) found that *D. fulvohirta* was a pillager of *Anthophora occidentalis* Cress. In southern Alberta, the wingless females of *D. fulvohirta* would be within reach of *A. occidentalis* while parasitizing *M. perihirta*, as the vertical clay banks that house *A. occidentalis* are topped by the prairie into which *M. perihirta* tunnels. As *N. lutea* lays its eggs in masses on the phyllaries of the buds of wavy-leaved thistle, *Cirsium undulatum* (Nutt.) Spreng., a favourite food source of *M. perihirta*, and as *A. occidentalis* also uses *C. undulatum* as a food source, investigations were conducted in whether *A. occidentalis* might be one of the principal hosts of *N. lutea* too.

The aggregation of *A. occidentalis* from which associations between it and its pillagers and parasites were determined was situated in a southwest-facing clay bank beside the St. Mary River near Lethbridge.

1Contribution from the Entomology Section.
2Entomologist.
3Assistant Technician.

This community of *A. occidentalis* and its associates has been observed occasionally over a period of years. Dr. R. W. Salt of the Lethbridge laboratory first observed it in 1940. He excavated parts of the bank at various times for species of *Hornia* Riley (Coleoptera: Meloidae) but found none.

Methods

Parts of the bank housing *A. occidentalis* was torn down on March 1, 1957. One hundred and seventy-three intact cells of this species were removed to the laboratory and placed separately in glass-topped tins. The bottoms of the tins were lined with blotting papers, which were wetted slightly at intervals to prevent desiccation of the immature forms within the cells. The *A. occidentalis* larvae from broken cells were handled similarly to obtain information on pupation. In addition, observations were made at the bank four times during the summer of 1957 and further excavations were made in January and February, 1958.

Anthophora occidentalis Cress.

About 61 per cent of the cells collected in 1957 contained *A. occidentalis* (Table I), and about seven per cent had been provisioned by *A. occidentalis* but showed no apparent development. On July 18, 1957, only males were seen at the bank; on July 26, many males were seen in tunnels but neither females nor the inverted chimneys they construct were seen. In January and February, 1958, none of the cells excavated contained *A. occidentalis.* The females had apparently moved to another nesting site.

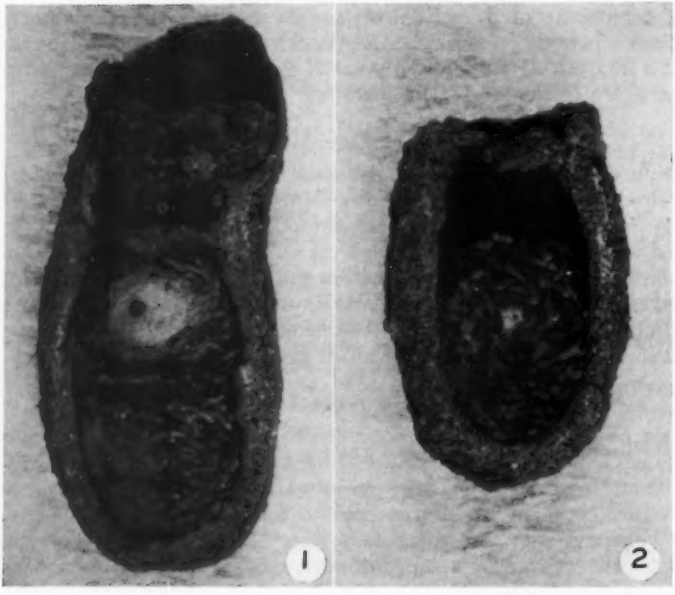
The increase in *A. occidentalis* males on July 26 over that on July 18 suggests that the flight period in 1957 began about mid-July. In the laboratory, 13 males emerged before the first female emerged, and the peak for male emergence was about 10 days earlier than for females. As populations of females of other solitary species of similar habits live for about 30 days (Hobbs, 1956), the flight period of *A. occidentalis* in 1957 possibly ended about the end of August.

A. occidentalis, was the only pioneer observed in the association in the bank near Lethbridge. All of the other species utilized the tunnels and cells excavated by *A. occidentalis,* or parasitized or pillaged the contents of the cells of this species or of the species inhabiting the *A. occidentalis* excavations.

Osmia (*Chalcosmia*) *texana* Cress. (Hymenoptera: Megachilidae)

When the bank was excavated in 1957, many *A. occidentalis* cells were occupied by *O. texana,* which were hibernating as adults within their cocoons. They were very sluggish and did not stand up or fly until the temperature of the room was raised to 85°F. Generally two cocoons containing males, which are much smaller than females, or one cocoon containing a female was found in each *A. occidentalis* cell. If the cell contained males, a deeply concave partition made of green plant material separated the cocoons (Fig. 1). If the cell contained a female, it was capped but not partitioned (Fig. 2). One *A. occidentalis* tunnel was found that had been partitioned into cell-sized compartments by *O. texana. O. texana* also sealed tunnel entrances with concave caps made of this same plant material.

The main source of plant material at this site was the stellate hairs on the surfaces of the leaves of scarlet mallow, *Sphaeralcea coccinea* (Pursh) Rydb. A female was watched as it removed the hairs from the leaves of this plant on July 18, 1957. Examination of several partitions that had been made the previous year indicated that these had also been made from the leaves of scarlet mallow.



Figs. 1, 2. 1, Cell excavated by *A. occidentalis* and partitioned by *O. texana*, and from which two males of *O. texana* emerged; 2, Cell excavated by *A. occidentalis* and capped by *O. texana*, and from which a female of *O. texana* emerged.

***Ancistrocerus catskill catskill* (Saussure) (Hymenoptera: Vespidae)**

This species and *O. texana* were the only species that took possession of old *A. occidentalis* excavations at the study site. The earthen plugs capping the *A. c. catskill* cells resembled those made by *A. occidentalis*. Two of *A. c. catskill* emerged from old *A. occidentalis* cells in 1957.

Nine of *A. c. catskill* emerged from *A. occidentalis* cells taken from the bank in 1940 by Dr. Salt. Nests of this species have been found in hollow bamboo stalks, old *Sceliphron* nests, old ground bee burrows, nail holes, and keyholes of a house (Boharr, 1951).

***Hornia minutipennis minutipennis* Riley (Coleoptera: Meloidae)**

H. m. minutipennis (MacSwain, 1958) was the most important of the pillagers and parasites of *A. occidentalis* in 1956; approximately 14 per cent of the *A. occidentalis* cells were pillaged by *H. m. minutipennis* (Table I). In other regions of North America where *Anthophora* spp. have been investigated, *Hornia* spp. were the most important of the insect enemies of the immature stages of *Anthophora* spp. (Hicks, 1926; Mickel, 1928; Linsley and MacSwain, 1942).

Females as well as males chewed their ways out of the earthen cells. Perhaps the artificial environment (one cell per glass-topped tin) prompted this atypical activity of the females, which usually mate and lay eggs within the cells in which they were born (Linsley and MacSwain, 1942; Bohart and Selander, 1955).

Some of *H. m. minutipennis* remain in diapause as prepupae until a succeeding year as do those of *H. boharti* Linsley (Linsley and MacSwain, 1945). Of the cells that were broken on March 1, 1957, two contained adults and five contained larvae of *H. m. minutipennis*. Seven of the cells from which nothing had emerged

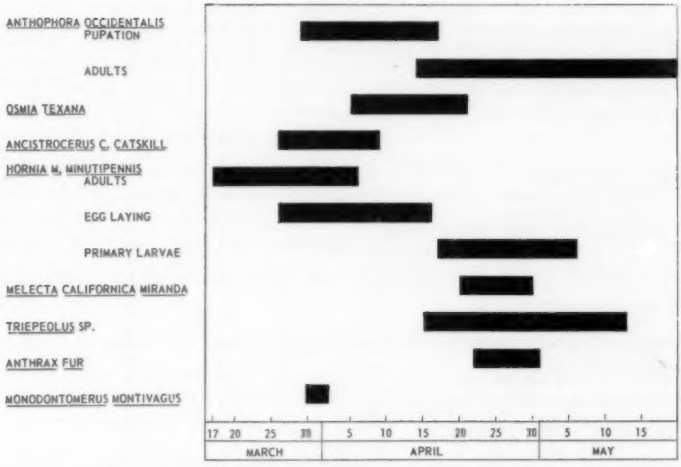


Fig. 3. Periods of emergence of adults of *A. occidentalis* and its associates, and information on other stages of some of the species at room temperatures in the laboratory from cells collected near Lethbridge, Alberta, on March 1, 1957.

by May 21, 1957, contained live specimens of *H. m. minutipennis;* four were pupae or adults within larval exuviae, and three were still larvae. Furthermore, in January, 1958, seven adults of *H. m. minutipennis* were found in cells of *A. occidentalis* made in 1956. In the laboratory, 14 adults (nine males and five females) emerged before the appearance of *A. occidentalis* (Fig. 3), which overwinters as prepupae; they emerged sufficiently early to mate and lay eggs before *A. occidentalis* began to emerge. However, the hatching period of *H. m. minutipennis* coincided with the emergence period of *A. occidentalis* (Fig. 3). Field observations also indicated that the primary larvae of *H. m. minutipennis* appeared when *A. occidentalis* began flying; they were seen swarming over the face of the bank and in and out of tunnel entrances on July 18 and on July 26, 1957. If as many were present during the flight period of *A. occidentalis* in 1956 as in 1957, it is remarkable that any of *A. occidentalis* survived. Perhaps the eggs laid by late-emerging or late-building specimens of *A. occidentalis* escaped predation by the *H. m. minutipennis* larvae as, in the laboratory, *A. occidentalis* continued to emerge for 15 days after the last eggs of *H. m. minutipennis* had hatched (Fig. 3), and, in the field, no primary larvae were seen on August 9, 1957, although it is likely that *A. occidentalis* would still have been flying at this time. If the above inference concerning escape is correct, it might explain why more males than females of *A. occidentalis* emerged from our (Table I) and from Mickel's (1928) samples: as a rule, these bees lay female eggs first, so that more males than females would escape predation by *H. m. minutipennis.*

Although the primary larvae of *H. m. minutipennis* could have moved directly into new *A. occidentalis* cells, they apparently found the host cells by attaching themselves to the bees that landed at tunnel entrances or on the face of the bank (cf. Bohart and Selander, 1955; Hocking, 1949). This retention by *H. m. minutipennis* of the instincts of flower-inhabiting ancestors may have relieved the pressure on *A. occidentalis.* The cells from which *H. m. minutipennis* emerged and the tunnels into which they crawled were ones taken over by *O. texana.* This

TABLE I

Numbers of *Anthophora occidentalis* Cress. and its associates that emerged or were removed from the intact cells of a sample from an aggregation near Lethbridge, Alberta, in March, 1957

	No. of cells	Percentage of total
Total	173	100
A. occidentalis, living males	57	33
living females	42	24
dead (all stages)	7	4
Hornia m. minutipennis Riley, living males	9	5
living females	5	3
living larvae	7	4
dead all stages	4	2
Triepeolus sp., living adults	6	3
dead adults	2	1
Meloid larvae in ?*Triepeolus* cocoons, dead	8	5
Anthrax fur O. S., living adults	6	4
dead adults	2	1
Melecta californica miranda Fox, living adults	3	2
Monodontomerus montivagus Ashm., living adults	2	1
Cells showing no apparent development	13	8

bee emerges before *A. occidentalis* and is a carrier of primary larvae but not a host. Thus most of the larvae would perish without contacting their hosts. As support for this hypothesis, live primary larvae of *H. m. minutipennis* were found attached to females of *O. texana* and dead ones were found among the detritus that surrounded the cocoons of *O. texana* in capped cells, but no adults emerged from the cells of *O. texana*. No other worker in this field has associated *Hornia* spp. with *Osmia* spp.; Hicks (1926) and Mickel (1928) reared only *O. texana* or chrysidids from *Anthophora* spp. cells capped with green plant material. Bohart and Selander (1955) believed that *O. texana* was immune to attack by *H. minutipennis*.

We did not look for the primary larvae of *H. m. minutipennis* on other than the host species or *O. texana*, but if they are like some species of *Nemognatha* Ill. and *Zonitis* Fabr. (Enns, 1956) they will attach to any moving object.

Species of *Hornia* are very prolific. Linsley and MacSwain (1942) found that *H. boharti* laid an average of 549 eggs. A single female of *H. m. occidentalis* Linsley laid 1,308 eggs (Linsley and MacSwain, 1942a). We mated one *H. m. minutipennis* male to one female, and another to three females. The four females laid 1212, 575, 757, and 878 eggs on fine moist soil in petri dishes. The numbers of eggs were related to the longevity of the females. Incubation of 22 daily samples at room temperature (71°±F.) was completed in 16-21 days with an average of 19 days. Almost all of the eggs were viable, including those that were laid last by the females that shared the same mate.

***Melecta* (*Melectomorpha*) *californica miranda* Fox (Hymenoptera: Apidae)**

Three of the 173 cells of *A. occidentalis* contained *M. c. miranda*. According to Linsley and MacSwain (1942) *M. c. californica* Cress. is a pillager. *M. c. miranda* destroys *A. occidentalis* (Mickel, 1928) and *A. bomboides neomexicana* Ckll. (=*A. neomexicana* Ckll.) (Hicks, 1926). *M. c. californica* is a pillager of *A. urbana* Cress., *A. edwardsii* Cress., *A. bomboides stanfordiana* Ckll., and *A. linsleyi* Timberlake (Linsley and MacSwain, 1942). In the laboratory the emergence of this species was synchronized with that of its host (Fig. 3).

***Triepeolus* sp. (Hymenoptera: Apidae)**

This anthophorid was found in four per cent of the intact *A. occidentalis* cells (Table I). According to Dr. P. D. Hurd, Department of Entomology and Para-

sitology, University of California, Berkeley, California, to whom the specimens of *Triepeolus* sp. were sent for identification, it is an undescribed species. Its emergence in the laboratory (Fig. 3) indicated that its flight period was synchronized with that of its host. One emerged from the *A. occidentalis* cell by cutting a circular hole in the cap with its mandibles, sometimes using one mandible as a pick to pull the earth back into the cell.

Little is known about the biologies of members of this group. Linsley and MacSwain (1942) state that *Triepeolus mojavensis* Linsley is a parasite of *A. linsleyi*. As the primary larvae of this genus have enormous heads and jaws (Michener, 1957), it is likely that they are pillagers as are *Melecta* and *Hornia* spp.

Eight dead meloid larvae were found in cells containing *?Triepeolus* cocoons (Table I).

***Monodontomerus montivagus* Ashm. (Hymenoptera: Torymidae)**

The chalcidoid *M. montivagus* emerged from two apparently intact cells of *A. occidentalis* (Table I). Adults of *M. montivagus* were commonly seen going in and out of tunnels on July 18, 1957, and were numerous on August 9. Mickel (1928) reported that this species "inhabited" 21 of 249 cells of *A. occidentalis*, and that *M. montivagus* did not emerge from cells excavated in the fall until after they had been subjected to cold. Rau (1926) and Frison (1922) presented evidence that there were two generations of *Monodontomerus* sp. a year. The above records indicate that Linsley and MacSwain (1942) were probably wrong in their assumption that the fertilized females of *M. montivagus* fly from April until the season ends and then hibernate until the following spring. More observations will have to be made in southern Alberta to ascertain whether there are more than one generation of this parasite of the prepupal stage of *A. occidentalis*.

Peck (1951) lists as hosts of this species the spruce budworm *Choristoneura fumiferana* (Clem.); megachilids of the genera *Anthidium*, *Dianthidium*, and *Osmia*; *?Melissodes* sp.; and *Xylocopa orpifex* Smith. At one *A. linsleyi* bank, *M. montivagus* was a parasite both of *A. linsleyi* and of its parasite *Photopsis auraria* (Blake) (Hymenoptera: Mutillidae); in the year it was studied it killed many more of the mutillids than of the anthophorids (Linsley and MacSwain, 1942).

***Anthrax fur* O. S. (Diptera: Bombyliidae)**

This parasite killed the occupants of eight of the 173 *A. occidentalis* cells (Table I). In the laboratory, its emergence period coincided with that of its host (Fig. 3). Various species of bombyliids have been associated with *Anthophora* spp. (Frison, 1922; Rau, 1926; Mickel, 1928).

***Chrysis* (*Chrysis*) *nitidula* Fabr. (Hymenoptera: Chrysididae)**

In 1940, Dr. Salt obtained five adults of this species from *A. occidentalis* cells that were being used by *A. c. catskill*. Bodenstein (1951) listed *C. nitidula* as a parasite of *A. catskill* on the basis of a single association made by Harrington (1898).

Summary

In a community of *A. occidentalis* near Lethbridge, *Osmia texana* and *Ancistrocerus c. catskill* utilized old *A. occidentalis* excavations. Enemies of the immature forms of *A. occidentalis* were *Hornia m. minutipennis*, *Melecta californica miranda*, *Triepeolus* sp., *Monodontomerus montivagus*, and *Anthrax fur*. *H. m. minutipennis* was the most important enemy at the time the nests were excavated. No enemies of the immature forms of *O. texana* were found. *Chrysis nitidula* parasitized *A. c. catskill*, and a meloid destroyed *?Triepeolus* sp.

Acknowledgments

We wish to express appreciation to Drs. N. S. Church, R. W. Salt, N. D. Holmes, W. O. Haufe, and G. E. Swailes of the Lethbridge Research Station for criticism of the manuscript.

References

Bodenstein, W. C. 1951. Superfamily Chrysidoidea. *In* Hymenoptera of America north of Mexico. Synoptic catalog, by C. F. W. Muesebeck, K. V. Krombein, H. K. Townes, and others, pp. 718-726. *U.S. Dept. Agr., Agr. Monogr.* No. 2.

Bohart, G. E., and R. B. Selander. 1955. New records of *Hornia minutipennis* Riley, with notes on its biology. Proc. Ent. Soc. Washington 57: 121-130.

Bohart, R. M. 1951. Family Vespidae. *In* Hymenoptera of America north of Mexico. Synoptic catalog, by C. F. W. Muesebeck, K. V. Krombein, H. K. Townes, and others, pp. 875-907. *U.S. Dept. Agr., Agr. Monogr.* No. 2.

Enns, W. R. 1956. A revision of the genera *Nemognatha*, *Zonitis*, and *Pseudozonitis* (Coleoptera, Meloidae) in America north of Mexico, with a proposed new genus. *Univ. Kansas Sci. Bull.* 37: 685-909.

Frison, T. H. 1922. Notes on the life history, parasites, and inquiline associates of *Anthophora abrupta* Say, with some comparisons with the habits of certain Anthophorinae. *Trans. Amer. Ent. Soc.* 48: 137-156.

Harrington, W. H. 1898. Canadian Hymenoptera, No. 7. *Canadian Ent.* 28: 75-80.

Hicks, C. H. 1926. Nesting habits and parasites of certain bees of Boulder County, Colorado. *Univ. Colorado Stud.* 15: 217-252.

Hobbs, G. A. 1956. Ecology of the leaf-cutter bee *Megachile perihirta* Ckll. (Hymenoptera: Megachilidae) in relation to production of alfalfa seed. *Canadian Ent.* 88: 625-631.

Hocking, B. 1949. *Hornia minutipennis* Riley: A new record and some notes on behaviour (Coleoptera, Meloidae). *Canadian Ent.* 81: 61-66.

Linsley, E. G., and J. W. MacSwain. 1942. The parasites, predators, and inquiline associates of *Anthophora linsleyi*. *Amer. Midl. Nat.* 27: 402-417.

Linsley, E. G., and J. W. MacSwain. 1942a. Bionomics of the meloid genus *Hornia* (Coleoptera). *Univ. California Pub. Ent.* 7: 189-206.

Linsley, E. G., and J. W. MacSwain. 1945. Longevity of fifth-instar larvae of *Hornia bohart*i Linsley. *Pan-Pacific Ent.* 21: 88.

MacSwain, J. W. 1958. Taxonomic and biological observations on the genus *Hornia* (Coleoptera: Meloidae). *Ent. Soc. Amer. Ann.* 51: 390-396.

Michener, C. D. 1957. Notes on the biology of a parasite bee, *Isepeolus viperinus* (Hymenoptera, Anthophorinae). *Ent. News* 68: 141-146.

Mickel, C. E. 1928. The biotic factors in the environmental resistance of *Anthophora occidentalis* Cress. (Hym.: Apidae; Dip., Coleop.). *Ent. News* 39: 69-78.

Mickel, C. E. 1928a. Biological and taxonomic investigations on the mutillid wasps. *Smithsonian Institution, U.S. Nat. Mus. Bull.* 143.

Peck, O. 1951. Superfamily Chalcidoidea. *In* Hymenoptera of America north of Mexico. Synoptic catalog, by C. F. W. Muesebeck, K. V. Krombein, H. K. Townes, and others, pp. 410-594. *U.S. Dept. Agr., Agr. Monogr.* No. 2.

Rau, P. 1926. The ecology of a sheltered clay bank; a study in insect sociology. *Trans. Acad. Sci. St. Louis* 25: 157-277.

(Received June 18, 1960)

Inducing Mating and Oviposition of the Warble Flies *Hypoderma bovis* (L.) and *H. lineatum* (De Vill.) (Diptera: Oestridae) in Captivity

By J. WEINTRAUB[1]
Canada Agriculture Research Station
Lethbridge, Alberta

Introduction

Certain investigations of the cattle grubs *Hypoderma bovis* (L.) and *H. lineatum* (De Vill.) have been hampered by difficulties in inducing the flies to mate and oviposit in captivity. For example, Parish (1955, 1957) suggested that infesting cattle with standard numbers of grubs would facilitate properly controlled experiments with therapeutic agents, and he attempted artificial insemination of the female flies toward this objective. In addition, procedures that would induce mating and oviposition in the laboratory could be used to analyse the reproductive behavior of the flies and the characteristics of the resulting cattle grub populations.

In laboratory experiments with virgin warble flies, using methods of tethered flight similar to those of Chadwick and Williams (1943) and Hocking (1953), it was observed that the genitalia of both males and females became active during and after some of the flights. These observations were utilized directly in inducing the females to lay eggs and were later associated with reported mating flights of Oestridae in developing a successful procedure for mating *Hypoderma*. A second method, following that of McDaniel and Horsfall (1957), made use of decapitated males to induce copulation. The procedures that were developed are described and the reproductive behavior of the experimental flies is compared with that of wild flies, as observed personally and as reported in the literature (Bishopp *et al.* 1926, Gansser 1951, 1956, Gebauer 1939, Hadwen 1919, Hammer 1942, Poulton 1904).

Mating

Description of the mating procedure refers to both *H. bovis* and *H. lineatum*.

Threads are attached with paraffin wax to the mesothoracic dorsa of newly emerged flies that have voided meconial fluid and hardened to flight condition. A male and female to be mated are flown on short leashes, one from each hand of the operator, and are permitted to come within range of each other (Fig. 1), with some guidance to prevent the threads from tangling and to maintain the male slightly above and behind the female. In these relative positions they circle and veer in flight for a few seconds until the male grasps the female. Though the flies seem to make contact haphazardly they are usually well situated to move into the final copulatory position, i.e., the male is perched with its forelegs resting on the head or pronotum of the female, its mid-leg tarsi hooked onto the wings of the female and the hind legs grasping the female abdomen. After a few such contacts the male abdomen rhythmically flexes antero-ventrally and the male shifts backward to a position where the moving surstyli and anal cerci can clasp the tip of the telescoped ovipositor (Fig. 2). The grappling interferes with the flight of the female, and the engaged flies are dropped to some surface for copulation. Usually the ovipositor is drawn out after being clasped by the male genitalia (Fig. 3) and the final mating (Fig. 4) is in the "median ventral position" (Richards 1927). During copulation, which lasts about three minutes (range

[1]Contribution from Veterinary-Medical Entomology Section.

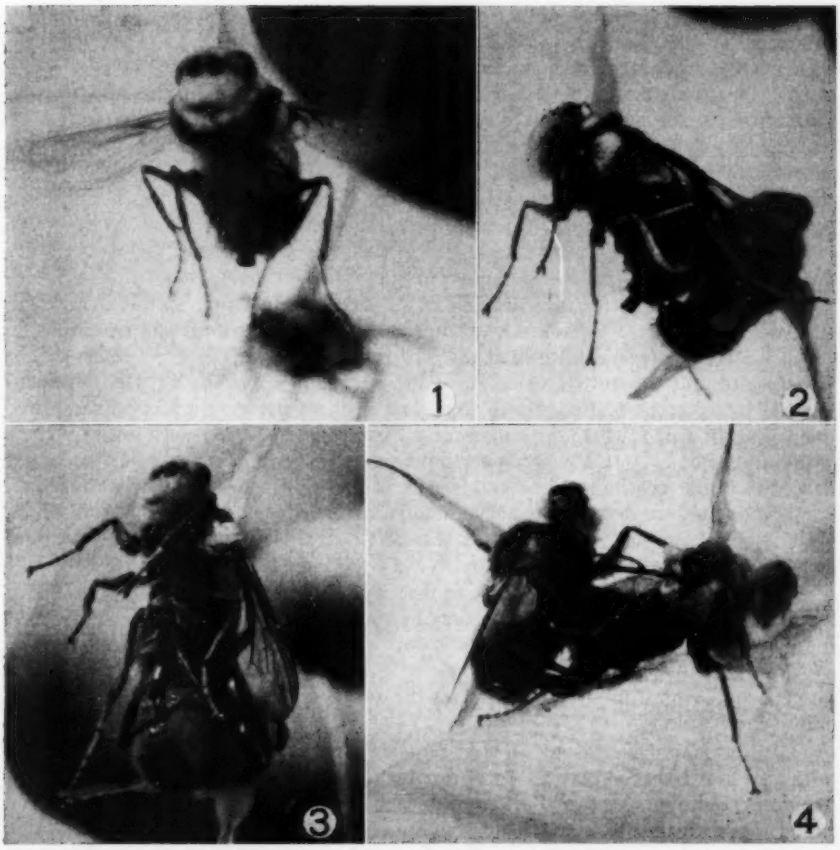
50 seconds to nine minutes), both partners seem to be in a semicomatose state in which the only visible activity is the rhythmic pumping of the male postabdomen. Disengagement is usually initiated by the male, which withdraws its genitalia by a final flexing of the abdomen while still on the female and steps off to rest or clean itself. After copulation both male and female sit and preen; the female usually makes a few tentative thrusts with its ovipositor, at the same time emitting drops of white meconial fluid. The whole procedure, including flying, contact and copulation, requires an average of about 15 minutes, with a range of about five minutes to two hours.

In the second method of mating the flies are mounted on threads as above and the male is decapitated. The flies are held by the waxed part of the thread so that they are oriented as in Figs. 2 and 3, but with the female held ventral side up. The male genitalia are stroked gently against the ovipositor until the clasping movement begins, usually in about two minutes. The male is then maneuvered so that its genitalia clasp the ovipositor and copulation takes place as in the final step of the flight method. The pair usually must be held in position during copulation because the legs of the male do not grasp the female properly. Copulation is often prolonged; individuals have had to be separated forcibly, in one instance after 23 minutes *in copula.*

Well over 300 pairs of each species have now been mated by the flight method at this laboratory and about 75 pairs including both species by the decapitation method. Both methods are laborious because each insect must be manipulated, but the latter method is quicker and the flies are easier to handle. Both are considerably more successful than spontaneous copulation of caged flies which Bishopp *et al.* (1926) and Gregson (1958) have reported for *H. bovis* and *H. lineatum,* respectively. We have observed this only four times in four years of programmed observations on more than 50 pairs of each species, and not at all among newly emerged flies in rearing cages. In each case copulation was preceded by a brief hovering flight of the male which alighted on or near the grounded female and moved into the copulatory position as in Fig. 4. Neither of the above references gave details of the circumstances under which the caged warble flies mated. It is probable that some flight activity was involved, for observations have shown that caged warble flies either remain inactive or are flying intermittently, depending on the temperature. Gebauer (1939) observed mating of newly emerged adults of *H. bovis* reared in a terrarium set into the window of his laboratory. He reported that the adults flew towards the light and mating occurred soon after the males and females came together. A description of the positions of the copulating pairs was given which corresponded to that of Fig. 4.

We have not seen mating by wild flies of either species in the field. Brief descriptions of the hovering of male Oestridae, including warble flies of cattle, have been given by Hammer (1942), Poulton (1904) and Brauer (1863). The hovering sites were associated with such prominent objects as mountain summits, isolated haystacks, trees and bushes, and isolated knolls or hills on otherwise flat terrain. Although it was stated that these aggregations served reproduction, no descriptions of mating of warble flies were given.

In Switzerland, Gansser (1951, 1956) was able to find the "meeting places" of warble flies after five years of searching and described the mating behavior in the field. The four meeting places discovered were permanent sites to which the warble flies came annually. The flies, of which about 95 per cent were males, appeared at a site at about the same time each day. Incidence of observed mating was low. These features appear to be similar to the swarming of Tabanidae (Blickle, 1959) and to that of various other Diptera (Dodge and Seago, 1954,



Figs. 1-4. Sequence of induced mating of *Hypoderma lineatum* by the flight method (photos retouched). 1, ♂ and ♀ flying on short tethers from the hands of the operator, ♀ in foreground; 2, ♂ grasping ♀ and moving backward as its genitalia move rhythmically; 3, Beginning of copulation; ovipositor of ♀ drawn out by the ♂ genitalia; 4, Lateral view of final copulatory position; ovipositor still drawn out.

Chapman, 1954), especially those whose larvae are parasitic on warm-blooded animals (Townsend, 1935). Gansser did not find swarms of warble flies around cattle even though cattle occasionally grazed in the vicinity of the meeting places during the fly season. He observed that the insects paired in flight, but the partners immediately dropped to the ground where they completed the act. He also witnessed flies pursuing each other and disappearing in the grass, but apparently could not determine whether copulation occurred. These descriptions suggest that the mating behavior of the warble flies in tethered flight is typical of what occurs in nature.

Oviposition

The ovipositor of virgin and mated females of both species becomes active during some of the tethered flights and in the intervening rest periods. After the first few flights the ovipositor is extended only when meconium is voided. How-

ever, after repeated flight and settling the ovipositor begins to extend rhythmically and oviposition follows. Thereafter, the activity of the ovipositor intensifies and eggs are laid indiscriminately on any available fibres, or may be deposited loosely. In this excited state a virgin female usually attempts to oviposit on the male when they engage in mating and the male genitalia cannot clasp the tip of the ovipositor. Therefore, in the procedure generally followed, the females are induced to mate before they are permitted to deposit any eggs.

The general method of inducing fertilized flies to infest cattle is the same for both species in that it utilizes this alternate flight and settling on the host where the eggs are laid on the hairs. However, the oviposition behavior is markedly different in the two species and the technique must be adapted accordingly.

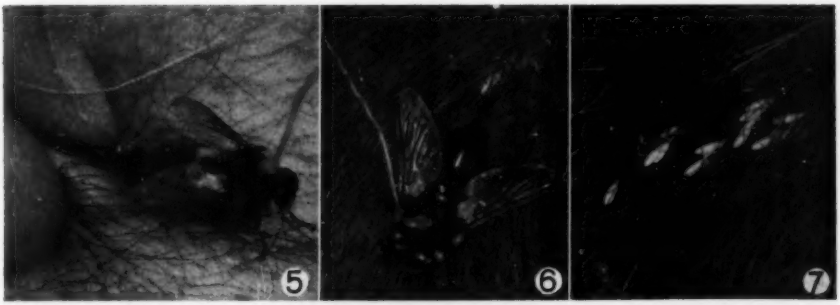
When a tethered fertilized female of *H. lineatum* lands on a cow, it raises its abdomen slightly and thrusts out its ovipositor repeatedly until the tip comes in contact with a hair. With a final upward twist, the two lateral processes of the 9th sternite and the 10th tergite grasp the hair and a row of eggs is deposited starting from the base (Figs. 5 and 6). The eggs are invariably laid on the lower surface of the hair (Fig. 7), as was observed by Gansser (1956) with wild fly eggs. The number of eggs laid may vary from two or three to as many as 25 or 30 per hair, depending on the state of activity of the fly and the suitability of the hair. Sometimes eggs are deposited on several adjacent hairs at one sitting. More often, after laying a single row the fly sits still or flexes the ovipositor feebly without egg-laying until it is flown again briefly.

When infesting cattle it is best to direct the flight so that the fly lands with its abdomen directed towards the bases of the hairs (Figs. 5 and 6). However, the ovipositor sometimes flexes to the sides or even bends antero-ventrally to lay eggs on dense hair. Among sparse hair of a human arm, only a hindward extension of the ovipositor is successful and the skin of the arm must be pinched to clump the hairs (Fig. 5).

The attacking behaviour of wild females of *H. lineatum* has been studied on both free and tethered cattle. In both cases the cattle usually show little sign of panic or gadding. All the 18 flies whose behaviour was observed closely showed similar actions; the fly circled the standing or recumbent host to its shady side where it settled on the ground, or directly on the host, and backed up with raised abdomen and thrusting ovipositor until the tip caught a hair on which the eggs were deposited. It then took off in a short flight and repeated the process a few times. All of the observed oviposition was on the legs and lower parts of the bodies of the cattle, as has been reported by Hearle (1938) and Hadwen (1919). However, Gansser (1956) found eggs of *H. lineatum* on the neck and shoulders of cattle in Switzerland. He also found that covering either the body or legs of the cattle did not prevent infestation and concluded that the flies might oviposit anywhere on the cattle.

The female of *H. bovis* deposits its eggs singly at the base of the hair with a hindward, sideward or downward jab of the ovipositor at the moment when it settles on the hide. Only rarely does it lay more than one egg without having to be lifted again for a short flight. Thus the procedure for infesting cattle becomes a matter of continually lifting and dropping the tethered fly every few seconds. Even if the female cannot fly some oviposition can be induced in this manner, though the number of eggs laid is much lower than with flying females.

Gebauer (1939), using reared *H. bovis* in an insectary, found that one female laid a large number of eggs when placed on a calf. It crawled upward depositing eggs as it proceeded. Hadwen (1919) caught wild flies and held them by the net on an animal's flank or back. The flies rested on the animal and pushed their



Figs. 5-7. Induced oviposition and eggs of *Hypoderma lineatum*. 5, Lateral view of ♀ ovipositing on hairs of human arm on which skin was pinched to clump the hairs; 6, ♀ ovipositing on hairs of dried untanned cowhide; 7, Eggs attached to undersides of hairs of the cowhide

ovipositors under the hairs at intervals. They rapidly laid a large number of eggs in a short time. However, we found that *H. bovis* did this only occasionally, when they were in the highly excited state described at the beginning of this section.

Close observation of wild *H. bovis* females attacking cattle in a corral showed the existence of two distinct types of ovipositing behavior. Twenty of the 25 flies observed behaved similarly to those described by Bishopp *et al.* (1926), Hadwen (1919) and Hearle (1938). Typically the fly first appeared in hovering flight low down at the hind legs of one of the cattle, from which position it darted at the animal a few times. After stamping and acting restless the animal would begin to gad, with the fly hovering about it and occasionally darting in to oviposit on the legs and lower parts of the body. The flies could be caught by net as the cattle ran past the observer in the restricted space of the corral. In the second type of behavior the fly would be seen hovering above one of the cattle and darting down to oviposit, then it would alight on the ground for a few seconds before pursuing the same animal or an adjacent one. When on the ground the fly could be captured by hand. In both types of behavior the flies transferred their attack from one animal to others that were running near by. Eggs were deposited mostly on the shoulders, back and tailhead of the animal, and infrequently on the sides and legs. This observation led to the use of the more convenient higher sites on the cattle in our infesting procedure, with no detrimental effects on the survival of the grubs.

The general pattern of behavior and movements of the ovipositor of wild females of both species were the same as those of the laboratory-reared and artificially mated females. Captured wild females that were tethered and put through the oviposition routine also behaved in the same way. The oviposition technique has been found to be consistently successful. More than 100 cattle have been infested by this method with 25 to 1,000 eggs per animal.

Checking the Fertility and Viability of the Eggs

Examining the eggs laid on the test cattle is the surest way of estimating their viability. Observations are made every second day, to conform with the minimum hatching time of two days (maximum 12 days) and to account for the empty egg-shells which are usually lost soon after hatching. The larvae emerge from the distal end of the egg (Fig. 8), move along the hairs and usually invade the host near the hatching site. However, we have evidence to show

that they may invade as far as 12 inches from the hatching site. Skin lesions, or "hypodermal rash" (Hadwen 1919), appear at the site of invasion but do not constitute quantitative indices of the number of larvae that hatched because the individual lesions usually merge with adjacent ones. They first appear about a day after the larvae have hatched, reach their peak of severity by about four to six days and finally leave faint scars a month later. On young calves they are generally in the form of faint but definite bumps; on older cattle they are seen as scabs of dried serum and blood in a general edematous area.

Almost 100 per cent of the eggs laid by a fertilized female develop larvae, and not fewer than 90 per cent hatch on the host. Occasionally fertilization is not accomplished by the mating although the mating and subsequent oviposition are indistinguishable from those of fertilized females. In these cases none of the eggs show development and they remain on the hairs for about a month. It is therefore desirable to have some indication of fertility soon after the cattle are infested by a fly. This is done by examining the spermathecae of the mated females after they have completed their oviposition. The tip of the ovipositor is grasped with forceps and pulled steadily until part of the oviduct with the attached accessory glands and spermathecae come free (Fig. 9). The three brown spermathecae are teased away, mounted in water on a slide, and cracked by pressure under a cover glass. The masses of rather large sperm that emerge from the broken shell are visible by the low power of a compound microscope (Fig. 10). It is also possible to see the active sperm within the spermatheca without cracking it. Occasionally sperm are not found in the spermathecae but eggs do develop. For example, in 1958, 94 females of *H. lineatum* and 93 of *H. bovis* were mated; in six of the *lineatum* and three of the *bovis* females no sperm were found but the eggs developed; in three other *lineatum* and seven *bovis* females sperm was not found nor did the eggs develop. Whenever sperm were found the eggs developed.

Samples of eggs that have been laid on hairs have been incubated at 30-36°C. for two to 12 days as an additional estimate of viability. Because the best incubating conditions still have not been determined this method is not satisfactory. Nor is it necessary since the other two methods are sufficient.

The procedures of mating and oviposition described here have been successful in about 90 per cent of the attempts under optimal conditions. The methods have also succeeded at such disparate localities as Kerrville and Lake Jackson, Texas[1] and Berkhamsted, Herts, England[2], after modification to suit local conditions.

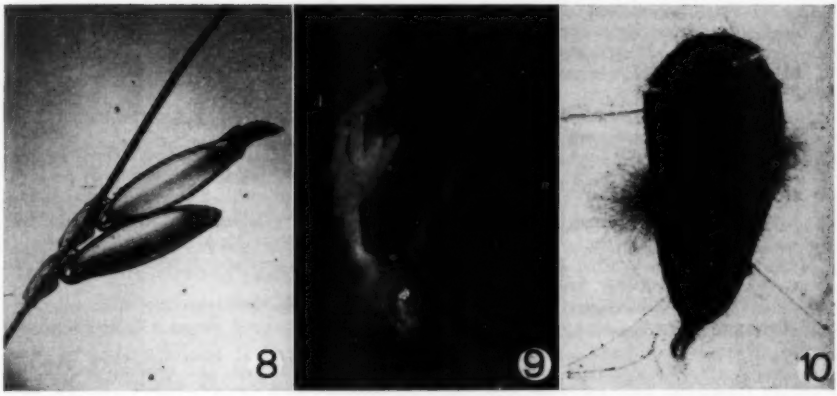
Summary

Warble flies (*Hypoderma bovis* (L.) and *H. lineatum* (De Vill.)) are induced to mate as follows: the candidate pair are flown on short threads and are permitted to make contact repeatedly until the male genitalia become active and grasp the ovipositor; the flies are then dropped to some surface to complete copulation. In a second method the male is decapitated and its genitalia stroked against the ovipositor until they become active; the flies are then moved into position to clasp the ovipositor in copulation. The behavior of the insects flying on threads is similar to that occurring among mating warble flies in nature.

To induce oviposition, the tethered, mated female is made to fly and settle on hairy cowhide a few times until its ovipositor becomes active. Thereafter

[1]Conducted by W. S. McGregor at the U.S. Department of Agriculture Laboratory, Kerrville, Texas and at the Dow Chemical Company, Agricultural Research Laboratory, Lake Jackson, Texas. (Personal communication).

[2]Conducted by L. C. Stones at the Cooper Technical Bureau, Berkhamsted, Herts, England. (Personal communication).



Figs. 8-10. Incubation of eggs and dissection of spermathecae to show viability and fertility of the eggs of *Hypoderma lineatum*. 8, Lateral view of incubated eggs, preserved with one larva in the act of hatching; no development in the other egg; 9, Dorsal view of internal genital system of the ♀; part of oviduct containing eggs extending upward at centre; accessory glands arranged to extend upward to the right; the three spermathecae are near the bases of the accessory glands; 10, Cracked spermatheca in water mount under low magnification of compound microscope, showing masses of sperm forced out of lateral cracks.

oviposition usually occurs whenever the fly is permitted to land. The female of *H. lineatum* moves backward on the hide and its ovipositor executes a series of thrusts until it grasps a hair upon which it deposits a row of eggs. Although it may oviposit on a number of hairs at one sitting it usually must be flown again before further oviposition takes place. The female of *H. bovis* flicks out its ovipositor and deposits a single egg at the base of a hair immediately upon contacting the hide. It must be flown briefly before each egg is deposited. The behavior of the flies during induced oviposition is similar to that of wild flies attacking cattle in the field.

The success of infestations on test cattle is checked by examining the oviposition sites for hatching of the eggs and for the presence of the "hypodermal rash". The success of fertilization is checked by examining the spermathecae of the females for the presence of sperm.

Acknowledgments

I am indebted to Messrs. R. H. Robertson, M. C. Qually and R. H. Gooding for assistance in many experiments through which the final procedures were developed. I am grateful to Drs. N. S. Church and W. O. Haufe of Lethbridge, Dr. A. C. Hodson of the University of Minnesota, and Dr. R. C. Bushland and members of his staff at Kerrville, Texas, for reviewing the manuscript.

References

Bishopp, F. C., E. W. Laake, H. M. Brundrett, and R. W. Wells. 1926. The cattle grubs or ox warbles, their biologies and suggestions for control. *U.S. Dept. Agr. Bull.* 1369. 120 pp. Washington, D.C.

Blickle, N. L. 1959. Observations on the hovering and mating of *Tabanus bishoppi* Stone. (Diptera, Tabanidae). *Ann. Ent. Soc. America* 52: 183-190.

Brauer, F. M. 1863. Monographie der Oestriden. Carl Veberreuter. Wien. 291 pp.

Chadwick, L. E., and C. M. Williams. 1943. Technique for stroboscopic studies of insect flight. *Science* 98: 522-524.

Chapman, J. A. 1954. Studies on summit frequenting insects in western Montana. *Ecology* 35: 41-49.

Dodge, H. R., and J. M. Seago. 1954. Sarcophagidae and other Diptera taken by trap and net on Georgia mountain summits in 1952. *Ecology* 35: 50-58.
Gansser, A. 1951. Dasselfliegen. Biologie, Schäden und Bekämpfung von Oestriden mit besonderes Berücksichtigung schweizerischer Verhältnisse. Zürich, Schweiz. Häutes-chädenkomm. 128 pp.
Gansser, A. 1956. Warble Flies and Other Oestridae. Biology and Control. Hide and Allied Trades Improvement Society. 63 pp.
Gebauer, O. 1939. Das Verhalten der grossen Dasselfliege (*Hypoderma bovis* De Geer) im Tierversuch und die perkutane Invasion der Larve des ersten Stadiums. *Z. Parasitenkunde* 11: 391-399.
Gregson, J. D. 1958. Recent cattle grub life-history studies at Kamloops, British Columbia, and Lethbridge, Alberta. *Proc. Xth Int. Congress of Ent.* (1956), 3: 725-734.
Hadwen, S. 1919. Warble flies, *Hypoderma lineatum,* Villers and *Hypoderma bovis* De Geer. *Can. Dept. Agr. Scientific Series* 27. 24 pp.
Hammer, O. 1942. Biological and ecological investigations on flies associated with pasturing cattle and their excrement. *Vidensk. Meddel. Dansk. Naturh. Foren., Kobenhavn* 105: 141-393.
Hearle, E. 1938. Insects and allied parasites injurious to livestock and poultry in Canada. *Can. Dept. Agr. Pub.* 604. 108 pp.
Hocking, B. 1953. The intrinsic range and speed of flight of insects. *Trans. Roy. Ent. Soc. London* 104: 223-345.
McDaniel, I. N., and W. R. Horsfall. 1957. Induced copulation of aedine mosquitoes. *Science* 125: 745.
Parish, W. E. 1955. The fight against warble fly. *Agriculture, London* 61: 574-577.
Parish, W. E. 1957. A summary of current research in the control of *Hypoderma* species of cattle. *in* Organization of control of warble fly infestation in cattle. The European Productivity Agency of the Organization for European Economic Co-operation. Paris. pp. 67-73.
Poulton, E. B. 1904. A possible explanation of insect swarms on mountain tops. *Trans. Ent. Soc. London,* 1904, pp. xxiv-xxvi.
Richards, O. W. 1927. Sexual selection and allied problems in the insects. The mechanical relation of the male and female genitalia. *Biol. Rev.* 2: 322-328.
Townsend, C. H. T. 1935. Manual of Myiology Part II. Charles Townsend and Filhos. Sao Paulo, Brasil. 296 pp.

(Received July 21, 1960)

Some Problems Associated with Weighing Aphids That Have Fed After Starving, as a Method of Measuring Intake of Plant Sap

By A. G. Robinson
Department of Entomology, The University of Manitoba

Introduction

In recent years, experimental research on feeding and nutrition of aphids has been closely associated with studies on host plant resistance or susceptibility to aphids. No satisfactory artificial feeding technique has yet been devised. Maltais (1952) and Day and Irzykiewicz (1953) have described methods using membranes, and reviewed the literature on previous attempts to induce plant-sucking insects to feed through membranes. Recently, Maltais (1959) has offered a promising alternative method using plant cuttings in organic nutrient solutions. His new technique was developed to exploit the findings of Mittler (1957) that the natural turgor pressure of willow apparently forced phloem sieve-tube sap up the stylets of *Tuberolachnus salignus* (Gmelin).

Several methods have been followed in attempts to evaluate aphid-host plant relationships. Recent reviews are those by Auclair (1958b), Painter (1958) and Kennedy and Stroyan (1959). Criteria used are measurements of size and weight of adult aphids; fecundity and rate of reproduction; host selection by alate forms; concentration of amino acids and sugars in host plants; mortality to nymphs or

adults; and rate and frequency of excretion of honeydew. This paper is concerned with some of the problems associated with weighing aphids as a method of measuring intake of plant sap, especially where periods of starvation are imposed as part of the method.

The first essential is that a clone of aphids be used in the tests. Harrington (1945) demonstrated the existence of five separate biological races, or biotypes, of the pea aphid, *Acyrthosiphon pisum* (Harris). Cartier (1959) recognized three biotypes of the pea aphid, based in part on differences of mean weights of adult apterous females. Cartier and Painter (1956) and Pathak and Painter (1958) distinguished differences in weight between biotypes of the corn leaf aphid, *Rhopalosiphum maidis* (Fitch).

The test aphids should be of approximately the same age. Adults should preferably be wingless, as winged forms are restless feeders, or may go considerable periods without feeding, especially during the time of host selection (see Taylor, 1959, for *Aphis fabae* Scop.). Nymphs are not favoured for feeding tests, because they are likely to cease feeding for a short time immediately before and after moulting. Newly emerged adults are not suitable, as Auclair (1958a) has shown that the pea aphid increases in weight from 3.810 mg. to 4.086 mg., from new adult to "bearing-adult". Also when a test extends over several hours, parturition may begin. Auclair (1958a) stated that nymphs of the pea aphid stop feeding for at least one hour during moulting, and that rate of excretion (presumably an indication of rate of feeding) decreased when adults were bearing young. Newly born nymphs of the pea aphid weigh slightly less than 0.2 mg. If several of these are born during a period between weight measurements, how are these losses to be corrected for?

Environmental conditions should be constant during the feeding or starvation periods. Schaefer (1938), Broadbent (1951), and Mittler (1958) have demonstrated the effect of evaporation on honeydew excretion. Maxwell and Painter (1959) found that rate of honeydew deposition by two species of aphids was affected by changes in temperatures, different plant parts as feeding sites, different varieties of plants, and the amount of light reaching the host plant and feeding site. Kennedy (1958) has discussed relations between aphid feeding and leaf age and development, and plant-water relations.

A further problem is what constitutes a satisfactory period of starvation so that aphids will feed readily, and how long should the feeding period be after starvation, in order to obtain reproducible data on weight gain. Hamilton (1935) measured volume of liquid imbibed from leaves by *Myzus persicae* (Sulz.). One hundred aphids were weighed collectively, starved for 14 hours, and showed a collective gain in weight after six hours of feeding. Watson and Nixon (1953) commented on the disadvantages of this method of measuring feeding rates. Pathak and Painter (1958) found that cornleaf aphids responded more consistently in the amount of the plant-liquid intake when they were kept without food for a period of 14 to 16 hours and then allowed to feed for three hours. They measured differential amounts of material taken up by four biotypes of cornleaf aphids from resistant and susceptible sorghums. In this connection the findings of Banks and Nixon (1959) with *Aphis fabae* Scop. should be noted, that apparently there was a very low rate of feeding for the first 12 hours of their test, followed by accelerated intake of plant sap between 12 and 16 hours. Bradley (1952) stated that aphids, even after fasting, do not necessarily settle down and feed continuously. Of 40 previously fasted *Myzus persicae*, none made a feeding puncture lasting longer than 20 minutes.

TABLE I

Gain or loss in weight of pea aphids feeding on broad bean after starving, 10 aphids each test, weighed individually, May 11, 1960.

Hours of starving	Average per cent loss in weight after starving	Hours of feeding	Average per cent gain or loss in weight after feeding
14	−25.5	3	−5.5
14	−20.9	6	+3.2
16	−21.5	3	−6.4
16	−21.9	6	−1.3
18	−23.5	3	−6.9
18	−23.3	6	+3.5

The following experiments were begun in an attempt to establish starvation-feeding test techniques to determine the extent of feeding of pea aphids on plants treated with maleic hydrazide (Robinson, 1959).

Methods and Results

When a Cahn Electrobalance (0-50 mg., accuracy ± 0.05%) was used it was necessary to immobilize the aphids before weighing. Aphids were subjected to a few seconds of below-zero temperatures, in the hope that they would be temporarily immobilized. However, it was found that subsequent exposure to the warm humid air of the room resulted in an increase in body weight due to condensation on the cold aphid integument. Attempts to use carbon-dioxide anaesthesia occasionally produced detrimental after effects. The only accurate method, which proved to be a very time-consuming one, was to place each aphid in an individual gelatin capsule, size No. 5 (Eli Lilly and Company). When a Roller-Smith microtorsion balance having a range from 0.05 to 100 mg. was used, aphids were simply placed free in the pan and quickly weighed.

Adults of the pea aphid, apterous summer viviparae not yet in parturition, were starved for 14, 16 or 18 hours and then placed in clip cages on broad bean plants (*Vicia faba* L.) to feed for periods of three or six hours. Results are shown in Table I. This test and several previous tests with both micro-balances showed that the average per cent loss in weight for the pea aphid varies between 15 and 25 per cent for any periods of starvation between 14 and 18 hours. This compares favorably with the data of Schaefer (1938) of pea aphid from pea seedlings where there was an average per cent loss of 14.4% in 12 hours of starving, and 21.9% in 24 hours, with rapid loss in weight by evaporation of body moisture during the first few hours of starving, followed by a levelling-off as the remaining body contents "concentrated". None of the three groups showed an average per cent gain after only three hours of poststarvation feeding. Of 29 individuals only nine showed a gain in weight in the three hours. Of those feeding six hours after starving, two groups out of three and 12 individuals out of 27 showed a small gain in weight. In none of 56 aphids was there a gain during feeding of the weight lost during starvation. Many produced nymphs while feeding, which must have contributed to further losses in weight. Also, gains in weight may have been due at least in part to the natural gains in weight during growth from young adult to "bearing-adult" mentioned above (Auclair, 1958a).

TABLE II

Gain or loss in weight of pea aphids feeding on broad bean after starving 14 hours, 10 aphids each test, weighed individually, May 16, 1960.

Average per cent loss in weight after 14 hours starving	Average per cent gain or loss after feeding	Average per cent further loss, no feeding	Average per cent gain or loss, continuous feeding	Average no. of nymphs produced during feeding
− 16.8	6 hours − 14.7			3.9
− 21.8	12 hours − 2.7			4.1
− 20.9	24 hours − 1.4			6.8
− 17.7		6 hours − 13.1		
− 19.4		12 hours − 21.1		
− 21.8		24 hours — 22.7*		
			20 hours − 11.5	6.7
			26 hours + 10.7	4.9
			38 hours + 15.4	9.4

*7 aphids out of 10 died before end of 38 hours.

A further test is reported in Table II. Adults nine days old which had begun reproducing were starved 14 hours, and then allowed to feed for periods of six, 12 or 24 hours.

The data in Table II indicate that even 12 and 24 hours of feeding after a period of 14 hours of starving may not be sufficient for an intake of plant sap that can be reliably measured as an increase in weight of the pea aphid. This is probably because of two reasons: the aphids begin producing young as soon as they resume feeding, and also begin excreting honeydew. Auclair (1958a) stated that the pea aphid excreted its own weight in honeydew in 18-32 hours. If rate of honeydew is approximately equal to intake of plant sap, one might even argue that the aphids could never regain their original "pre-starving" weight!

Mean weights of pea aphids after several days of development on plants, as used by Cartier (1959) and Maltais (1959) should show with reasonable accuracy gains or losses due to nutrition. But the data shown in Tables I and II indicate that weighing either young adult pea aphids or those which have already begun reproducing, after starving, is not a suitable method of measuring intake of plant sap during immediate subsequent hours of feeding.

Summary

Problems which arose during attempts to weigh pea aphids are discussed. Adult pea aphids not yet in parturition were weighed individually, starved for 14, 16 or 18 hours, weighed, fed for periods of three or six hours on broad bean, and weighed again. In a further similar test pea aphids which had begun reproducing were starved for 14 hours, and fed for six, 12 or 24 hours. Both tests indicated that feeding periods up to 24 hours after starving, are not sufficient for an intake of plant sap by the pea aphid to be reliably measured. This is probably because aphids resume excretion of honeydew as soon as they resume feeding, and also because they begin producing nymphs as soon as they resume feeding.

References

Auclair, J. L. 1958a. Honeydew excretion in the pea aphid, *Acyrthosiphon pisum* (Harr.) (Homoptera: Aphididae). *J. Ins. Physiol.* 2: 330-337.

Auclair, J. L. 1958b. Developments in resistance of plants to insects. *Ann. Rep. Ent. Soc. Ontario* (1957) 88: 7-17.

Banks, C. J., and H. L. Nixon. 1959. The feeding and excretion rates of *Aphis fabae* Scop. on *Vicia faba* L. *Ent. Exp. et Appl.* 2: 77-81.

Bradley, R. H. E. 1952. Studies on the aphid transmission of a strain of henbane mosaic virus. *Ann. Appl. Biol.* 39: 78-97.

Broadbent, L. 1951. Aphid excretion. *Proc. R. Ent. Soc. Lond.* (A) 26: 97-103.

Cartier, J. J. 1959. Recognition of three biotypes of the pea aphid from Southern Quebec. *Jour. Econ. Ent.* 52: 293-294.

Cartier, J. J., and R. H. Painter. 1956. Differential reactions of two biotypes of the corn leaf aphid to resistant and susceptible varieties, hybrids and selections of sorghums. *Jour. Econ. Ent.* 49: 498-508.

Day, M. F., and H. Irzykiewicz. 1953. Feeding behaviour of the aphids *Myzus persicae* and *Brevicoryne brassicae*, studied with radiophosphorus. *Aust. J. Biol. Sci.* 6: 98-108.

Hamilton, M. A. 1935. Further experiments on the artificial feeding of *Myzus persicae* (Sulz.). *Ann. Appl. Biol.* 22: 243-258.

Harrington, C. D. 1945. Biological races of the pea aphid. *Jour. Econ. Ent.* 38: 12-22.

Kennedy, J. S. 1958. Physiological condition of the host-plant and susceptibility to aphid attack. *Ent. Exp. et Appl.* 1: 50-65.

Kennedy, J. S., and H. L. G. Stroyan. 1959. Biology of aphids. *Ann. Rev. Ent.* 4: 139-160.

Maltais, J. B. 1952. A simple apparatus for feeding aphids aseptically on chemically defined diets. *Canadian Ent.* 84: 291-294.

Maltais, J. B. 1959. Feeding the pea aphid, *Acyrthosiphon pisum* (Harr.) (Homoptera: Aphididae), on plant cuttings in organic nutrient solutions. *Canadian Ent.* 91: 336-340.

Maxwell, F. G., and R. H. Painter. 1959. Factors affecting rate of honeydew deposition by *Therioaphis maculata* (Buck.) and *Toxoptera graminum* (Rond.). *Jour. Econ. Ent.* 52: 368-373.

Mittler, T. E. 1957. Studies on the feeding and nutrition of *Tuberolachnus salignus* (Gmelin) (Homoptera· Aphididae). I. The uptake of phloem sap. *J. Exp. Biol.* 34: 334-341.

Mittler, T. E. 1958. The excretion of honey-dew by *Tuberolachnus salignus* (Gmelin) (Homoptera: Aphididae) *Proc. R. Ent. Soc. Lond.* (A) 33: 49-55.

Painter, R. H. 1958. The study of resistance to aphids in crop plants. *Proc. Tenth Int. Congr. Ent.* (1956) 3: 451-458.

Pathak, M. D., and R. H. Painter. 1958. Differential amounts of material taken up by four biotypes of corn leaf aphids from resistant and susceptible sorghums. *Ann. Ent. Soc. Amer.* 51: 250-254.

Robinson, A. G. 1959. Note on fecundity of the pea aphid, *Acyrthosiphon pisum* (Harris), caged on plants of broad bean, *Vicia faba* L., treated with various plant growth regulators. *Canadian Ent.* 91: 527-528.

Schaefer, C. W. 1938. Physiological conditions which produce wing development in the pea aphid. *J. Agr. Res.* 57: 825-841.

Taylor, L. R. 1959. Abortive feeding behaviour in a black aphid of the *Aphis fabae* group. *Ent. Exp. et Appl.* 2: 143-153.

Watson, M. A., and N. L. Nixon. 1953. Studies on the feeding of *Myzus persicae* (Sulz.) on radioactive plants. *Ann. Appl. Biol.* 40: 537-545.

(Received June 8, 1960)

THE RUNGE PRESS LIMITED, OTTAWA
Mailed: Friday, February 24, 1961